OILFIELD TECHNOLOGY

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Unconventional Gas takes centre-stage

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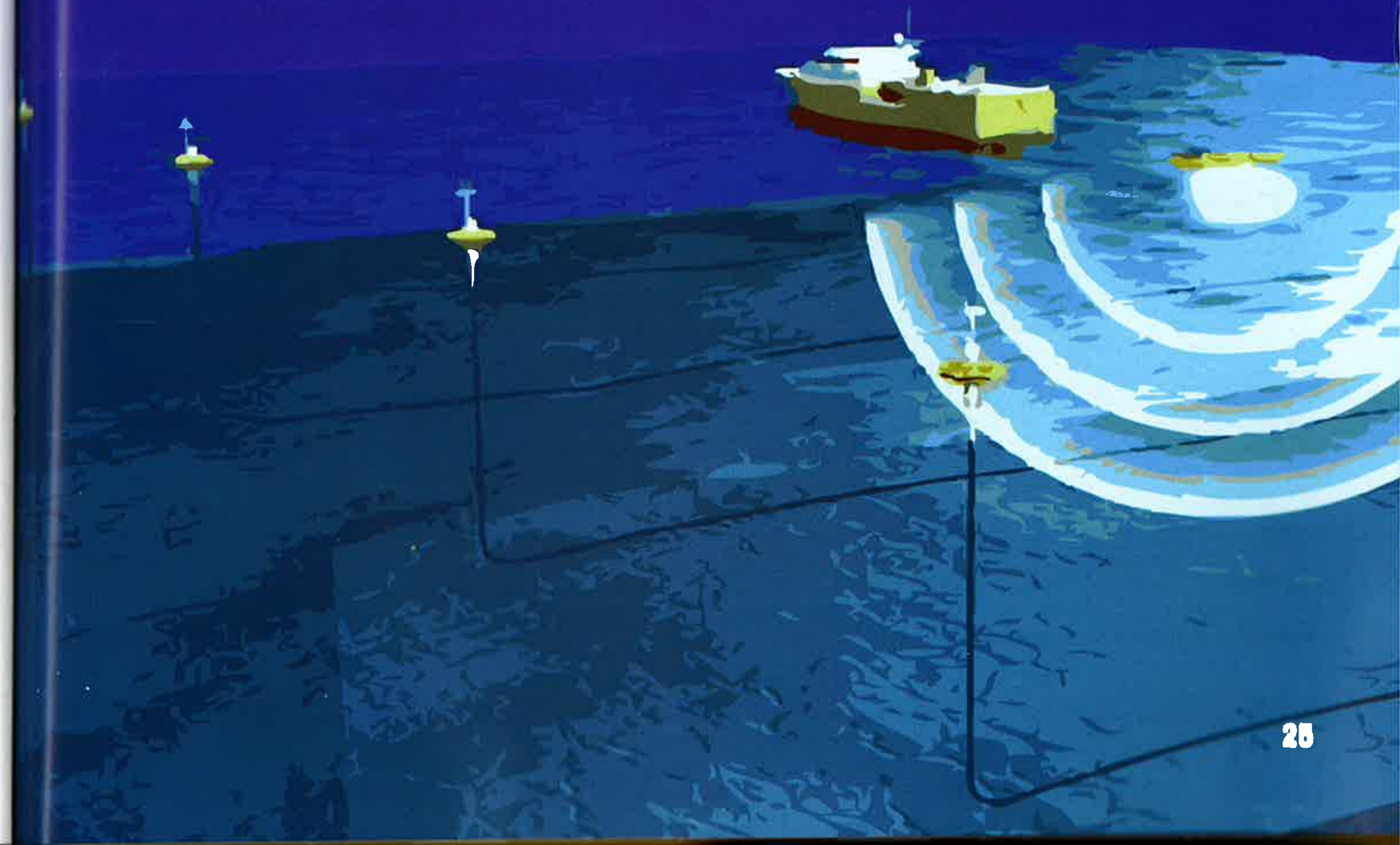
Dr Atef Ebed, Reservoir Exploration Technology ASA, Norway, explores the application of new seismic technology offshore the United Arab Emirates.

GOOD ENOUGH *for the Gulf*

While the use of ocean bottom cable (OBC) seismic data in the Arabian Gulf is not new, a field study was undertaken in 2008 offshore the United Arab Emirates (UAE) to investigate whether the enhanced imaging capabilities of the latest generation of OBC systems seen elsewhere in the world would be observed in this geophysically challenging area, where the combination of a hard water bottom and shallow water gives rise to very significant guided wave noise.

Placing sensors on the seafloor was the first way marine seismic data were ever acquired but ocean bottom seismic data acquisition has remained a minority activity in offshore exploration and production seismic terms worldwide. Historically there were a number of technical issues that were responsible for this, but recent advances in instrumentation have addressed a number of these limitations and OBC surveys are increasingly being employed for appraisal and development applications where conventional towed streamer acquisition is either impractical or does not deliver the image quality required for the development of the field.

There are a number of technical benefits that arise from placing stationary seismic sensors on the seafloor:



- The noise arising from towing the sensors through the water is eliminated.
- The noise induced by the movement of the sea surface, so called weather noise, is reduced.

In published comparisons between streamer and OBC data, OBC data exhibit significantly lower noise levels than conventional streamer data.[1-2]

Another advantage that results from placing the receivers on the seafloor is the ability to locate shots and receivers independently. This allows any source/receiver geometry to be employed. For conventional towed streamer operations only narrow azimuth swath geometries can be acquired.

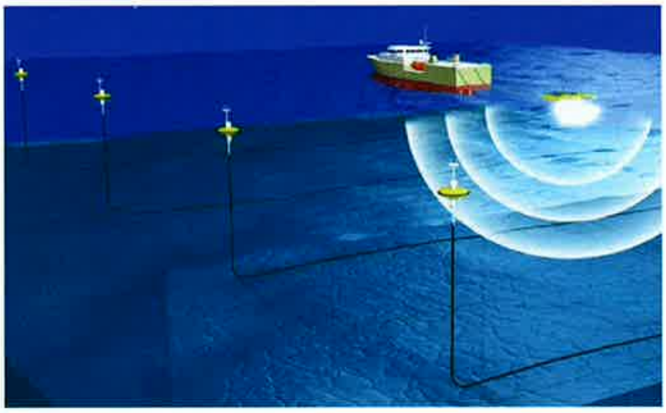


Figure 1. *Schematic of single vessel OBC crew in operation.*

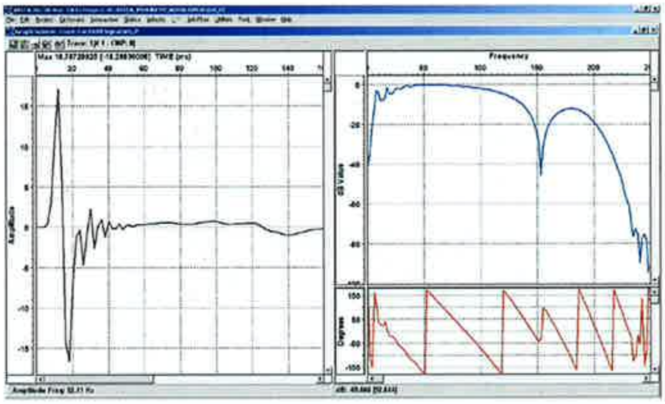


Figure 2. *724 in.^{3} source array signature, amplitude and phase spectra.*

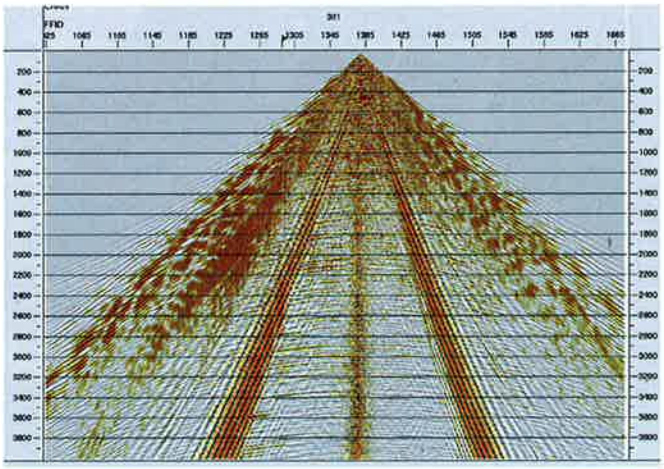


Figure 3. *Raw hydrophone common receiver gather.*

The separation of source and receiver also allows both split spread and forward/reverse shot data to be acquired, thus improving both signal/noise ratio and providing updip/downdip data, which can be of considerable advantage in high dip environments such as those associated with salt intrusions, or where fault imaging is of critical importance.

For deeper target imaging, longer offset data is increasingly required with offsets as large as 12 - 15 km being specified by the oil companies. While it is possible to tow such long streamers in open waters, in most producing areas surface obstructions and oilfield traffic render this extremely difficult if not impossible. Further, the manoeuvrability of streamer vessels towing such cable lengths is very limited and the efficiency of towed streamer operations, due to the resulting long line change times, is severely compromised, especially for field specific surveys.

Multicomponent sensors

By deploying multicomponent sensors, either two component (2C) (one hydrophone and one geophone or accelerometer) or four component (4C) (one hydrophone and three orthogonal geophones or accelerometers), on the seafloor rather than just hydrophones, the OBC approach offers further advantages over towed streamer.

Hydrophones detect pressure, which is a scalar quantity, i.e. there is no direction associated with the measurement. Thus the output from a hydrophone has the same polarity (is positive or negative) for a pressure wave travelling up from a subsurface reflector as for a pressure wave reflected down from the sea surface.

Geophones or accelerometers detect ground motion velocity or acceleration, which are vector quantities, i.e. there is a direction associated with the measurement. Thus the output from a geophone or accelerometer has a different polarity depending on whether the ground motion is due to a wave reflected up from a subsurface reflector or down from the sea surface.

Combining the data from scalar and vector sensors, often referred to as dual sensor summation, is a straightforward process to separate the recorded data into upward and downward travelling components. The resulting data have no receiver side sea surface ghost and thus the water depth in the survey area does not compromise the bandwidth of the dual sensor data.

Field study

The field study was conducted offshore Abu Dhabi (UAE) in July 2008 using a VectorSeis Ocean (VSO) system manufactured by ION Geophysical, which uses three component MEMS accelerometers in place of traditional geophones. The survey was able to be acquired using a single vessel since the VSO system uniquely utilises a standalone recording buoy for each 1000 data acquisition channels and thus no recorder vessel is required unlike traditional OBC systems.

By eliminating the recording vessel conventionally employed for OBC operations, a number of commercial and operational benefits can be achieved:

- Reduced operational cost.
- Reduced HSE risk.
- Improved access in congested producing oilfield areas.
- Reduced noise: no recording vessel DP noise impacting near offset seismic stations.

The 2D receiver line was laid out approximately North-South. Three 6000 m cables were deployed, end to end, to achieve the desired 18 km receiver line length.

Since one of the objectives for the field trial was to acquire PS converted wave data in addition to P-wave data, the shot offset had to be extended to accommodate the 'skew' of the conversion point towards the receiver, since the upcoming shear wave has a much lower velocity than the downgoing P-wave.

A relatively small source array volume of 724 in.^{3} was selected for the trial in order to minimise the low frequency output of the source, as this low frequency energy is a significant component in the guided wave noise that is characteristic of seismic data in the survey area.

The impulse response and amplitude spectrum of the array are shown in Figure 2.

The 2D nature of the field trial required only a single transit of the source vessel, nominally 25 m to the east of the receiver line, and a second transit was made, nominally 25 m to the west of the receiver line, to provide a robust 'hybrid' receiver positioning solution based on both acoustic transponders at 300 m intervals along the receiver cables and first break picks every 25 m.

Data

The main objective of the 2D data processing, which was undertaken by the GX Technology division of ION Geophysical, was to preserve the bandwidth of the data while minimising the high amplitude guided wave energy, which dominates the raw shot records shown in Figure 3.

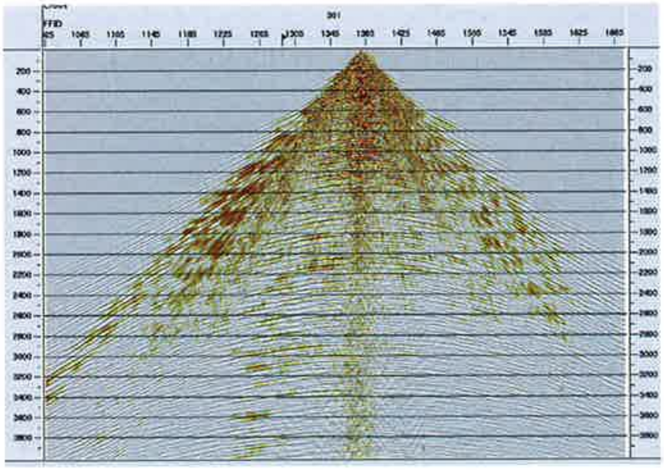


Figure 4. *Common receiver gather after de-noise.*

After noise attenuation to suppress both boat and guided wave noise, the reflected energy can be readily observed, as illustrated in Figure 4.

Due to the shallow water depth along the survey line, which ranges from 12 - 24 m, the receiver ghost notch falls within the seismic bandwidth and to address this dual sensor summation is used. This summation is undertaken prestack.

The strong velocity contrasts in the near surface generate significant multiple energy and, despite the relatively flat relief of the geological layering offshore UAE, a Hi-Rez Tau-P de-multiple was

Figure 5. *Dual sensor stack.*

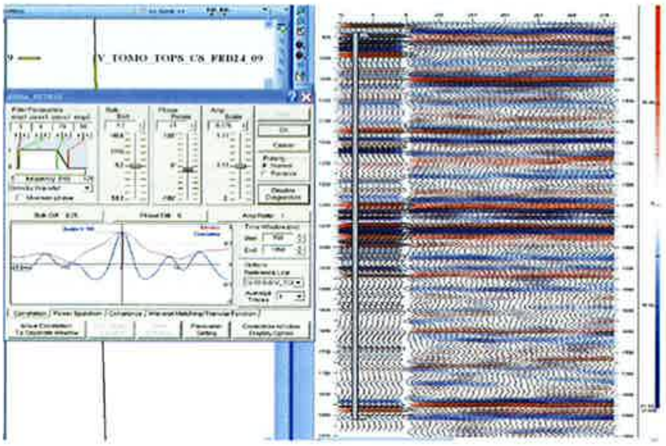


Figure 6. *Well tie - no stretch/squeeze applied.*

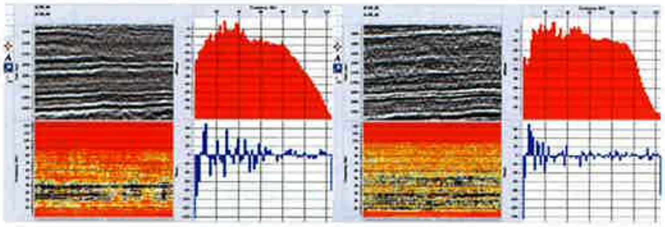


Figure 7. *Spectra centred on Thamama before (left) and after (right) Gabor deconvolution.*

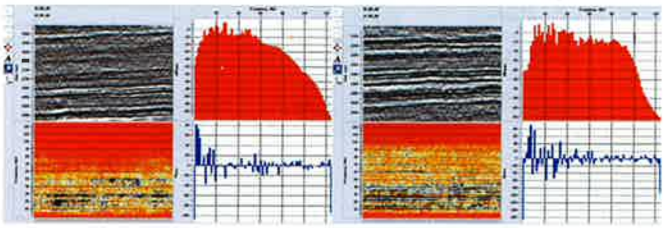


Figure 8. *Spectra centred on the Arab Formation before (left) and after (right) Gabor deconvolution.*

required in addition to a Gabor deconvolution. The latter, due its time varying nature, acts as a data driven inverse Q-filter on the data.

The data were prestack time migrated using an anisotropic prestack algorithm, followed by the application of a High Resolution Radon de-multiple. A 26° phase rotation was applied to tie to a well along the survey line.

The quality of the well tie is shown in Figure 6, where the cross correlation coefficient between the well synthetic and the 2D PreSTM data is 0.79.

Not only does the data exhibit excellent continuity and good signal to noise, but the bandwidth at the target horizons, namely the Thamama and the Arab formations, after the application of Gabor decovolution, is very high, as shown in Figures 7 and 8.

The improvement in bandwidth (the -10 dB level increases from approximately 50 Hz to more than 80 Hz) is clearly seen in the zoomed sections. Similar improvements are seen for the Arab formation.

The improvement in bandwidth (here, the -10 dB level increases from below 60 Hz to almost 90 Hz) is again clearly visible in the windowed seismic sections.

The improved low end performance of the VSO system allows the recovery of frequencies that are significantly lower than that achieved by previous generation OBC and streamer systems. The stationary nature of the sensors in the OBC method eliminates the low frequency tow noise that contaminates towed streamer systems and allows true single receiver point recording. Resolution is a function of bandwidth, not just the highest frequency recorded, and the wideband nature of the VSO data that have been acquired in this field trial has allowed the Gabor deconvolution applied to these data to deliver very high quality 2D data.

Conclusion

Although only a limited volume of 2D data were acquired, the high standard of the field test data is evidenced by the quality of the tie to the well over which the test line was acquired. The high bandwidth is observed in the data at the ARAB levels and the performance of the acquisition system has allowed advanced state of the art processing algorithms to deliver very high resolution images of the subsurface. These results offer the promise that when high density spatial sampling and wide band sensor response used in this test are applied for 3D or 4D applications in the survey area, superior reservoir delineation and characterisation will be achieved.

Improved resolution seismic data are needed to increase hydrocarbon recovery from existing reservoirs. This field test demonstrates that the application of the latest seismic technology both in acquisition and in processing can deliver the 'development quality' data needed for such applications in the Arabian Gulf.

References

1. WALKER, et al, 2006, SEG 'Enhanced imaging with seafloor seismic compared to towed streamer.'
2. BOELLE et al, SEG, 2005, 'Sparse receiver and multi-azimuth simulations from a high fold OBC campaign in the UK North Sea.'

Acknowledgments

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