Q-Marine seismic acquisition results: report from WesternGeco

Last year, our Special Topic on marine seismic acquisition featured the design objectives and technology behind WesternGeco's Q-Marine. In that issue, Leif Larsen, now marine vice president and general manager, stated that the company was reticent about publishing intermediate processing results from Q-Marine until the initial commercial surveys were properly completed. One year later, processing of the huge volumes of data has been completed for several projects. Here is WesternGeco's update.

Q-Marine is the outcome of a 10-year programme that began with a Schlumberger research project to identify the most significant sources of noise in seismic data. This was followed by the development of new seismic technology to suppress or minimize that noise. The resulting system particularly addresses variations in source characteristics and receiver sensitivity, swell noise from wave action, and positioning errors associated with receiver groups. In addition to improved resolution and bandwidth, the system delivers properly calibrated data for 4D time-lapse analysis of reservoir fluid movement.

Noise attenuation

The Q-Marine system records data from closely spaced single sensors. The combination of single-sensor recording and fine spatial sampling enables attenuation of noise using data-adaptive software, which is much more effective than hard-wired analogue systems and also better preserves signal amplitude. This feature delivers reservoir-quality data from shallow towed streamers without jeopardizing acquisition efficiency. Figure 1 shows a shot record recorded using a streamer towed at 5 m during force 7 weather conditions in the North Sea.

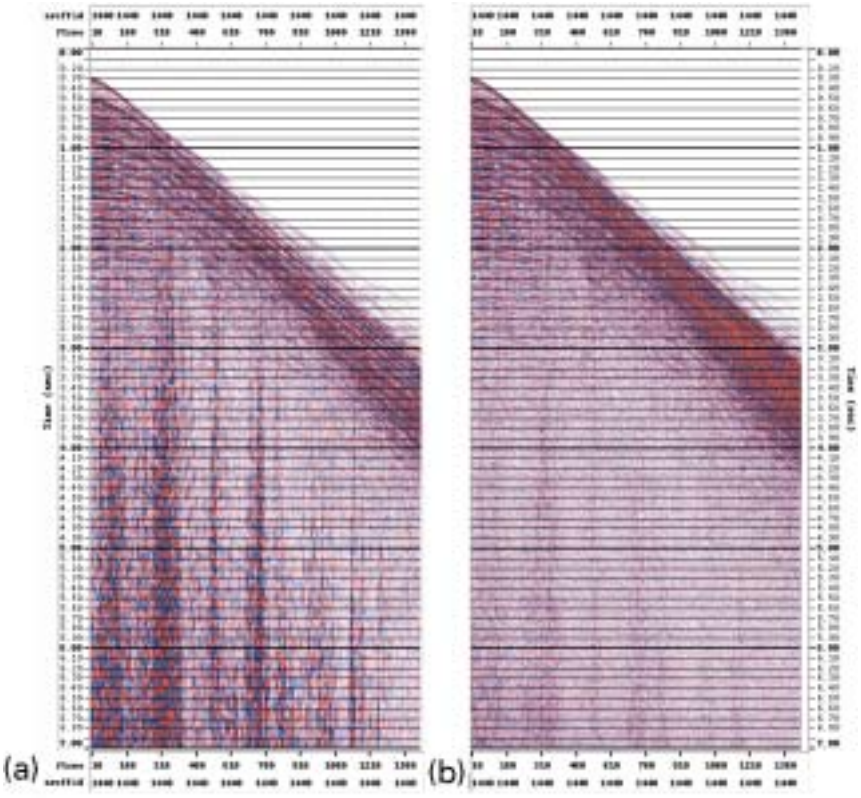

Figure 1 Shot record recorded in marginal weather. Conventional analogue group forming (a) is ineffective at removing swell noise. Q-Marine (b) removes the noise while retaining signal fidelity.

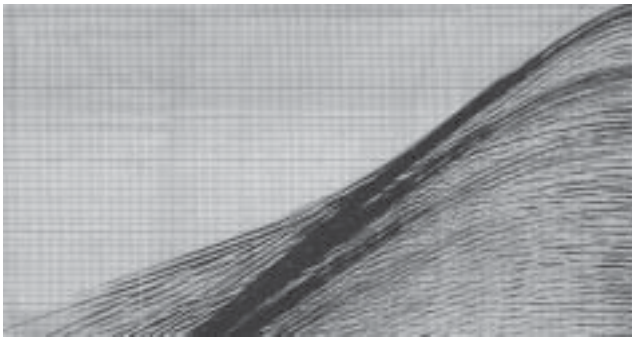

Figure 2 Shot record from a Q-Marine survey using a 12 km streamer. Excellent signal-to-noise ratios continue through wide-angle arrivals beyond the water-wave, which are necessary to reveal weak sub-basalt returns. Part of the iSIMM project, see article in this issue p. 782 and visit http://www.badleys.co.uk/isimm-public.

On the left is the simulated result of analogue group forming, which is integral to conventional recording systems, showing considerable swell noise. On the right are the results of Q-Marine digital group forming (DGF), where intelligent noise removal is applied before data reduction. After stack and migration, uncalibrated wave-generated noise will become less apparent, but will nevertheless degrade signal fidelity and mask changes due to fluid movement in 4D studies. Removal of noise at an early stage also improves the effectiveness of prestack processing algorithms and analysis such as AVO.

Recent trials in the Faroes area have demonstrated the dramatic improvement in noise attenuation enabled by the Q-Marine system for long offset surveys (see separate article on p. 782). Figure 2 shows excellent signal-to-noise ratios on wide-angle arrivals beyond the water-wave, which will be necessary to reveal weak returns such as in sub-basalt environments.

Bandwidth and resolution

Several features of the Q-Marine system lead to an improvement in bandwidth and resolution. Not least of these is the ability to tow the streamers at a shallower depth without compromising noise levels or creating survey downtime. This is a result of the improved effectiveness of data-adaptive noise attenuation relative to conventional methods. Q-Marine also features the Calibrated Marine Source (CMS) system to compensate for shot-to-shot variations caused by, for example, slight changes in the timing and air pressure of different guns, wave action and by variations in the geometry of the gun array. This not only improves the bandwidth and resolution of each survey, but also removes a major perturbation from the time-lapse signal.

Figure 3 shows a comparison between Q-Marine data and conventional data from the North Sea Magnus field and their corresponding FX spectra. The Q-Marine data show improved frequency content both on the high and low side, leading to much improved imaging of thin sands.

A high resolution event mapped on another North Sea Q-Marine survey was found to correspond to a sand body just 26 ft thick at the well location, previously unseen on surface seismic data

Well ties

Broader bandwidth and calibrated sensors, including better source phase control through CMS, enables a deterministic data processing flow. This results in an improved match between Q-Marine surface seismic data and well data, providing more accurate and reliable reservoir models. Figure 5 is an

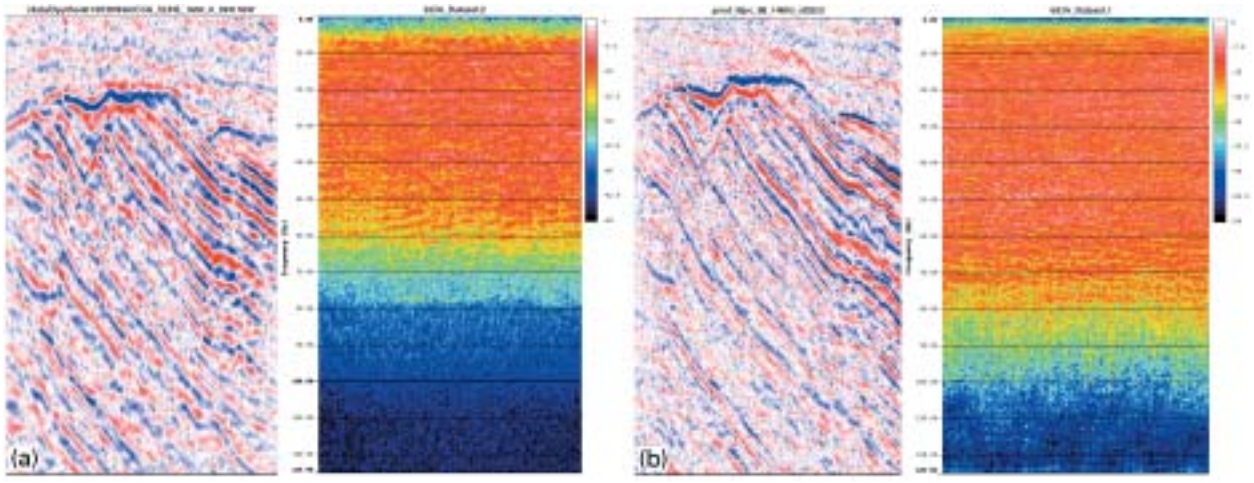

Figure 3 Conventional data (a) and Q-Marine data (b) from the North Sea Magnus field and their corresponding and FX spectra.

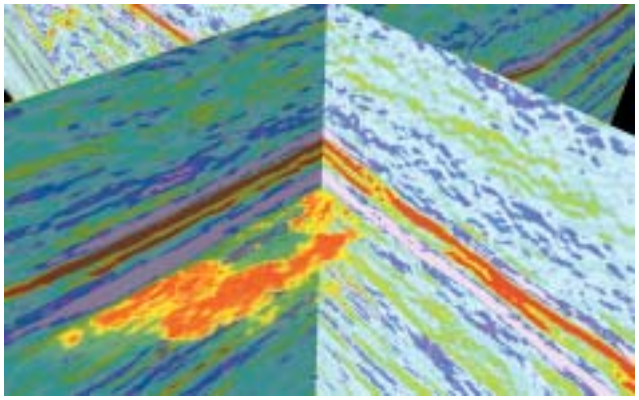

Figure 4 Q-Marine data enabled mapping of a sand body known to be 26 ft thick at the well location.

example from the North Sea showing an excellent well tie with the surface seismic and its acoustic impedance inversion.

Calibrated seismic data

During the design process behind Q-Marine it soon became clear that precise repetition of survey geometry is a key success factor for time-lapse surveys. This requirement was the main driver behind the development and patenting of the active streamer steering and positioning system. Calibration of the source and receivers removes further noise from the 4D signal while removal of swell noise improves both data quality and repeatability.

Figure 6 shows, in the left hand panel, 3D data from a North Sea survey. The middle panel shows 3D data from a test swath shot in the same location some days later using active streamer steering to match the receiver positioning of the first survey. During this period, there would be no change in subsurface geology, including pore fill, so no coherent 4D signal would be expected. Positioning of the repeat swath was within a few meters of the baseline swath for most of the test. Processing for each swath included only independent deterministic processing, with no attempt at cross-equalization between the baseline and repeat data. The right hand 'difference' panel shows no visible signal energy and provides a clear demonstration of the repeatability of the system.

Every new 3D survey shot using the Q-Marine system is considered to be a 4D ready baseline, providing high repeatability for subsequent surveys. The system was launched quite recently, so there have not yet been any repeat surveys using Q-Marine separated by a significant period of hydrocarbon production. In the meantime, the system provides a high fidelity, broad bandwidth dataset for 4D analysis with improved backward compatibility to optimally match the configuration of legacy conventional datasets through streamer steering and flexibility of sampling. Further improvements in dataset matching are achieved through a robust processing sequence and, due to minimized perturbations from the acquisition system, decreased reliance on cross-equalization.

Most industry analysts agree that the majority of the world's remaining oil and gas reserves are in known reservoirs. Twenty years ago, it was expected that an average of approximately 40% of oil in place could be economically recovered from North Sea fields. In many cases, 60% recovery is now considered to be a reasonable target, due to improved seismic imaging and drilling and completion technology. Further improvement in recovery factors requires quantitative measurement of the remaining oil and gas and the uncertainty of these measurements. Q-Marine provides the tools to more accurately map faults, thin beds and bypassed hydrocarbon-bearing zones, so is helping to further increase the value of mature fields.

Obstructed areas

A further benefit of active streamer steering and accurate positioning is that it enables the Q-Marine system to record data

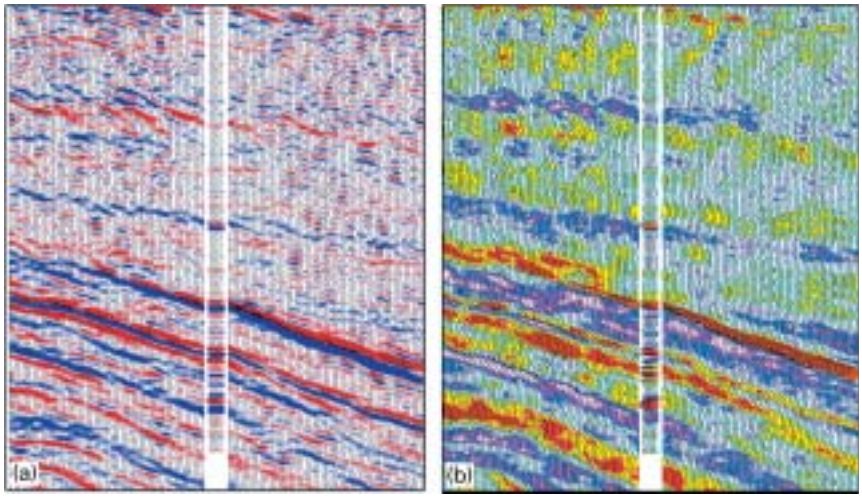

Figure 5 North Sea example of tie between synthetic seismogram and surface seismic (left) and acoustic impedance derived from downhole measurements with inverted surface seismic data (right).

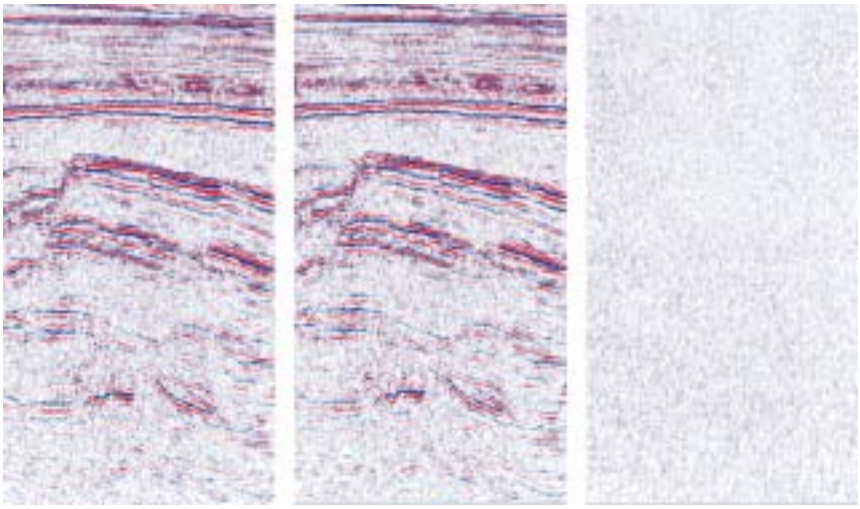

Figure 6 Baseline, repeat section and difference section for a 3D profile acquired using streamers steered for repeat positioning. Data courtesy of Statoil and its partners Conoco and Fortum, Norway Licence PL095.

closer to obstructions with a reduced risk of collision or streamer tangling. This improves the coverage and data quality around such obstructions and reduces the need for ocean bottom cables. The system has been used to pass streamer tow points as close as 25 m from obstructions. In addition to streamer steering, careful project planning based on actively monitored currents ensures the safety of the in-sea equipment at such close proximity.

Figure 7 shows an analysis of the differences between a base and monitor survey measured in the overburden of Statoil's Norne field. Both surveys used a second source vessel to undershoot the Norne FPSO. The yellow line shows the area of reduced coverage in the base survey, which was acquired using a conventional seismic system. The red line shows a much smaller area of reduced coverage for the Q-Marine survey (Eiken *et al*. 2002). Streamer steering and carefully planned and run operations provided improved azimuth and offset distribution around the obstruction.

Q-Marine is just one element of a suite of seismic services provided by WesternGeco under the name Q-Reservoir, which is focused on providing E&P companies with the right information to make critical drilling, development, and production decisions with increased confidence. Q-Reservoir services include locating the reservoir through improved definition of reservoir geometry for increased confidence in well placement; defining the nature of the reservoir by quantitatively measuring reservoir facies, pore space and hydrocarbon phase to optimize reserve estimates and development planning; and monitoring changes in reservoir saturation and pressure over time to ultimately maximize the recovery of hydrocarbons.

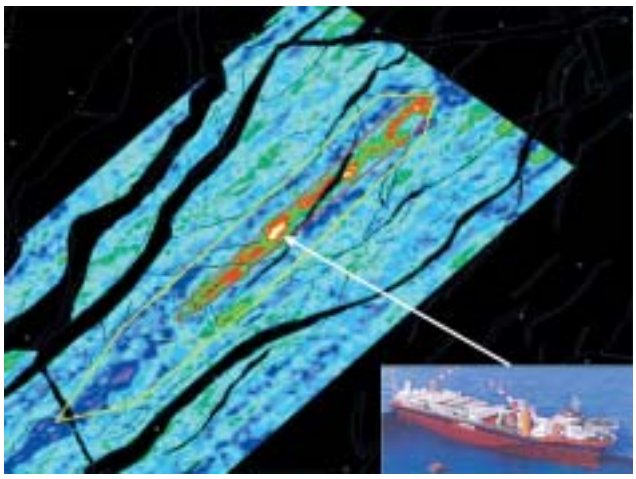

Figure 7 The yellow line shows the zone of reduced coverage for the base (conventional) survey. The red line shows the much smaller area of reduced coverage for the Q-Marine survey. The background is an analysis of the difference between Norne base and monitor surveys measured in the overburden.

WesternGeco is more convinced than ever of the value of Q-Marine and is continuing to deploy the system on its core 3D fleet as and when vessels are ready for upgrading.

References

Eiken, O., Aronsen, H., Furre, A-K., Klefstad, L., Haakon, L., Nordby, L. and Osdal, B. [2002] Repeated seismic surveys from the Norwegian Sea using new Streamer Technology. *SEG International Exposition and 72nd Annual Meeting*, 6–11 October 2002, Salt Lake City.