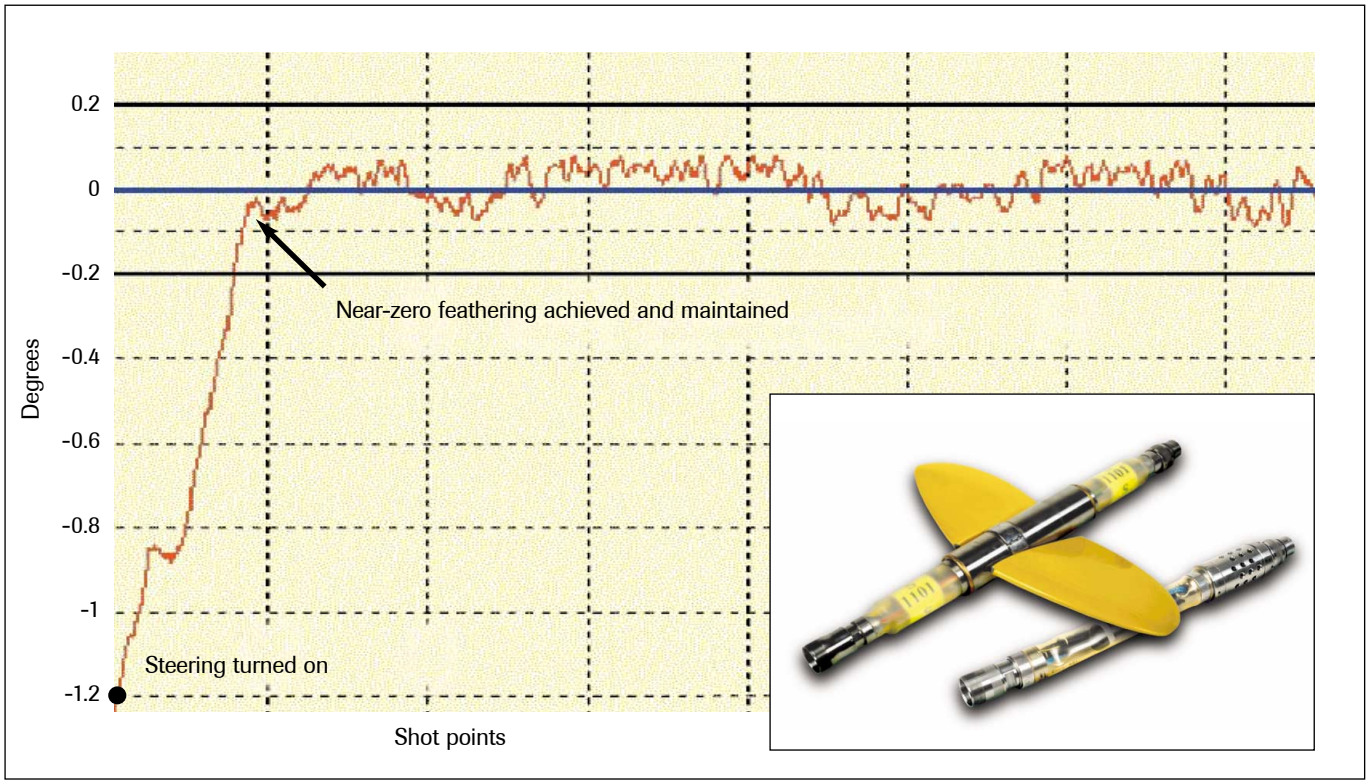


The Q-Fin streamer steering device enables reliable and repeatable cable positioning vertically and laterally.

Processed to perfection

A major source of environmental perturbations that seriously affects data quality and repeatability is the vibration that occurs in streamers due to sea swell. Q-Marine records swell noise with sufficient spatial fidelity to eliminate it using targeted filtering techniques. Unlike conventional random noise suppression, this does not significantly affect the signal bandwidth or fidelity. By dramatically reducing swell noise, high quality seismic data can be recorded in poor weather, reducing survey acquisition times and speeding up exploration decisions.

The improvement in the low frequency signal-to-noise ratio provides for more accurate imaging and inversion to accoustic impedance.

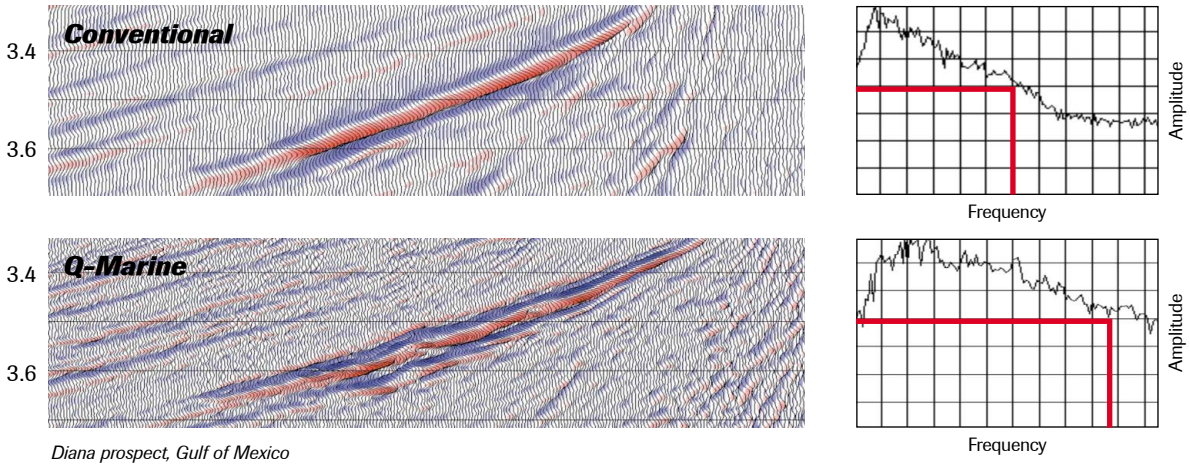
The removal of swell noise makes Q-Marine data repeatable so that it can reliably be used in time-lapse surveys. Q-Marine seismic is 4D Ready.

Steerable streamers - on target, over time

The Q-Fin streamer steering devices are controlled wings that are integral to the slim Q-Marine streamer for low noise. Steerable streamers and a fully braced front-to-back acoustic positioning network enable crossline separations as small as 25 m and steering for optimal coverage and repeatability. While conventional acquisition systems allow control of streamer depth, the Q-Marine system also enables active horizontal steering in addition to depth control. The result: more accurate receiver positioning for reduced errors in processing and improved repeatability for 4D seismic surveys.

Safe and sound

Q-Fin allows direction changes with a tight line spacing to be made more safely and with less chance of tangling streamers. It also reduces risk of fouling or loss of streamers and other in-sea equipment when towing past navigation hazards. Streamer control and accurate separation during deployment and retrieval, along with less time spent in handling streamers on the back deck, equate to safer operations.



Diana prospect, Gulf of Mexico

Single-sensor processing results in broadband and highly resolved results for more accurate imaging, as seen in this example.

Q-Marine: the future of seismic

Enhanced applications of seismic technology such as imaging for production well placement, pore pressure prediction, and monitoring fluid fronts require extremely accurate data. Q-Marine's fully calibrated single-sensor system delivers:

- Uncompromised 3D wavefield acquisition
- Dense inline and crossline spatial sampling
- Flexibility in streamer positioning for optimized wavefield sampling
- Accurate positioning for advanced imaging and moveout correction
- Intelligent noise filtering
- Improved signal fidelity
- Shot-by-shot designature

Q-Marine provides the critical factors needed for enhanced reservoir definition and successful 4D surveys — low noise, high-resolution sampling, and repeatable measurements through its unique calibrated and controllable source, sensor, and positioning systems.

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WesternGeco

Marine services

Q-Marine

Imaging the invisible – repeatably

Q-Marine*, the world's only fully calibrated single-sensor marine seismic acquisition and processing system, delivers the seismic technology breakthrough needed for new-generation reservoir management. Q-Marine provides exceptional data quality, unsurpassed repeatability, reduced survey time, and the highest levels of operational safety.

New horizons

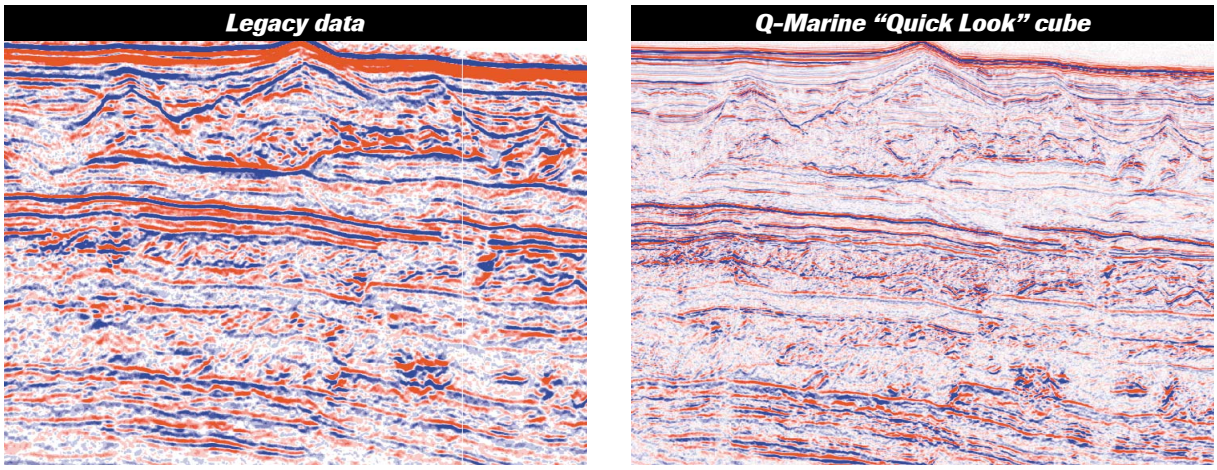
Sophisticated seismic techniques are the cornerstone of today's exploration successes. However, as the industry looked beyond exploration and began to apply seismic technology to reservoir management tasks, it became increasingly clear that a step change in seismic quality was needed. For reservoir applications, a good image is not enough. With the prospect identified from conventional 3D, the reservoir geophysicist must see beyond the image in order to understand the subtle messages hidden in the details of amplitude and phase at the reservoir level.

Conventional exploration 3D has allowed the industry to reach a real success plateau. Unique next-generation technology from WesternGeco now brings a new dimension to reservoir management.

Whether imaging complex structures, observing subtle fluid movements, analyzing seismic attributes and amplitudes, or optimizing the illumination of multiple targets, Q-Marine will improve results.

High resolution, low-noise data and the freedom to group single-sensor signals give geophysicists an edge in 3D interpretation — every Q-Marine survey can be processed to satisfy diverse objectives. New levels of repeatability also make Q-Marine data 4D Ready — every Q-Marine survey can be a baseline time-lapse survey.

WesternGeco



Europa field, Gulf of Mexico *- The Q-Marine data (right) show a dramatic resolution improvement over the conventionally acquired and processed legacy data (left).*

Calibration delivers lasting quality

Q-Marine addresses three main barriers to acquiring quality seismic data:

- Variations in seismic source and receiver characteristics
- Uncertainty in hydrophone positioning
- Swell noise produced by wave action on the receivers

The result is repeatable, quality data that reflect the subsurface, not the acquisition system. Q-Marine's fully calibrated sensors, sources, and positioning ensure that the response of each component, from source to processing, is known and accounted for. The resulting 3D wavefield is of unprecedented accuracy – corrected for position, amplitude, and timing errors.

Source calibration

The signature of an airgun source array is known to vary from one shot to the next, depending on variations in the individual airgun firing-times, chamber pressure dropout, and array geometry. These shot-to-shot variations reduce the accuracy and repeatability of seismic data.

With Q-Marine, an advanced digital source controller provides a properly calibrated marine source, ensuring that an accurate signature can be derived for every shot. Q-Marine uses the Notional Source method to compute the effective output of the source array. This method uses recordings of the acoustic pressure field made by the near-field hydrophones at each gun position to compute a far-field signature on a shot-by-shot basis. A recent development in this method allows for the direct comparison of lines shot under different weather conditions and with different equipment, bringing new confidence to amplitude interpretation.

Hydrophone calibration

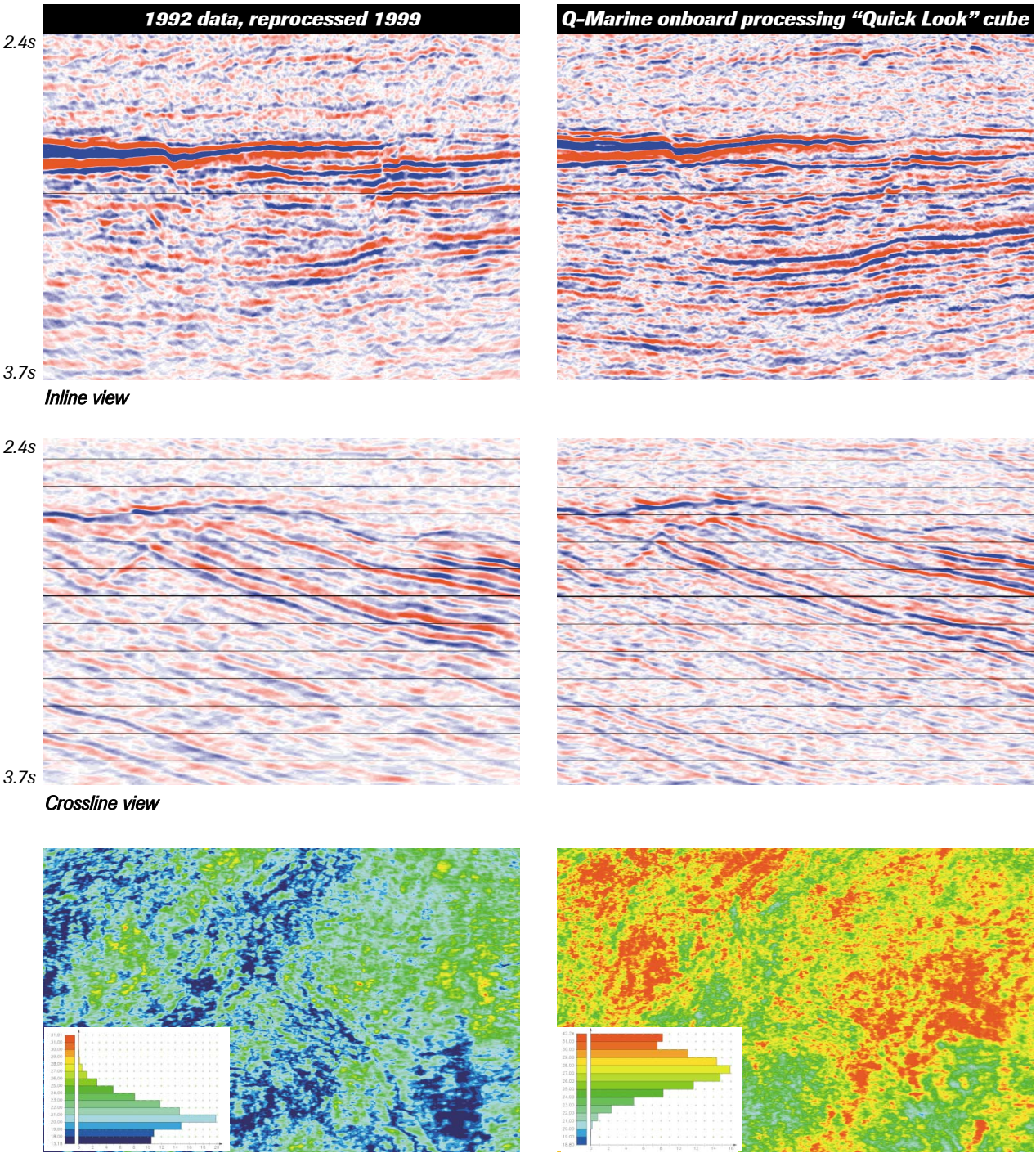
Well-defined source signatures are complemented in the Q-Marine system by a new tubular hydrophone design and calibration procedures that produce high-fidelity responses and faithfully preserve the received signal amplitude. Each of the high-fidelity tubular hydrophones is delivered from manufacturing with its own sensitivity certificate. These values are stored in the streamer electronics for automatic data calibration.

Q-Marine provides fine spatial sampling as well as fully flexible receiver array response through group forming performed digitally in the recording or processing system. Digital Group Forming (DGF) and processing grid-size parameters can be varied during processing to deliver multiple solutions, each optimized for different survey objectives. Additionally, the fine sampling enables powerful new filtering techniques to remove coherent noise within the DGF operation. This allows the streamer to be raised to a shallower depth, thereby recording higher frequencies with less noise.

Positioning calibration

High-resolution marine seismic surveys need close streamer separation. But that is not enough. Each hydrophone position must be known accurately. Q-Marine includes a novel technique to monitor the hydrophone positions. Instead of using compasses to estimate streamer shapes, the new positioning system provides a full streamer acoustic network, independent of streamer length.

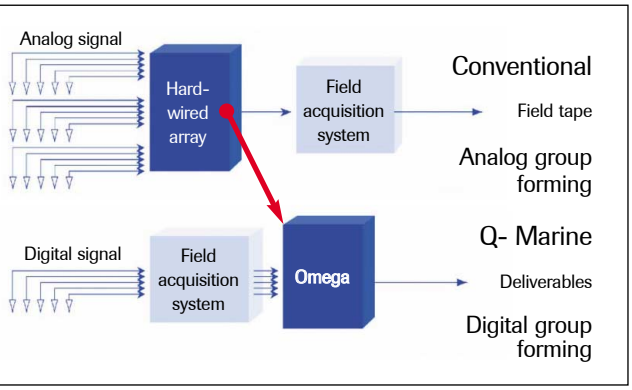
Newly developed acoustic sources based on spread spectrum technology and binary codes are placed typically at 800 m intervals along the streamers. The



Areal view *- The Q-Marine example on the right shows a 35% improvement in central frequency.*

Magnus field, North Sea *- These three examples show inline, crossline, and areal views from the Magnus field. The data on the left were shot in 1992, reprocessed in 1999, and were considered "best-to-date." The examples on the right are initial "Quick Look" onboard processing cubes from Q-Marine. The reservoir sands are below the base Cretaceous unconformity at a reflection time of approximately 3 s.*

(The survey was conducted for the BP Exploration Operating Co. Ltd., Nippon Oil Exploration and Production U.K. Ltd., Agip U.K. Ltd., and Petrobras U.K. Ltd. WesternGeco has agreement from BP to show the data and publish a paper on the survey results. BP has not yet stated that they endorse the technique, but are conducting a full comparative analysis of the data with WesternGeco.)



Single-sensor data may be group formed to meet specific reservoir requirements.

seismic hydrophones also act as receivers for this positioning signal. The absolute positioning accuracy achieved anywhere in the seismic spread is better than 3m.

While this positioning accuracy contributes to improved 3D processing, it is absolutely essential for time-lapse, or 4D, seismic monitoring that requires not only accurate, but repeatable positioning.

Singular performance

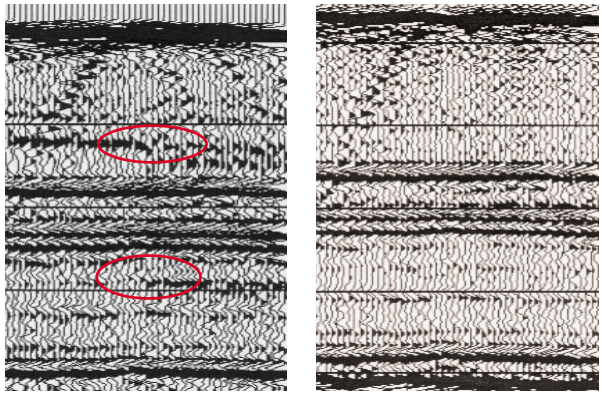
It has long been desirable to acquire seismic data from individual hydrophones in order to eliminate many of the traditional sensor grouping deficiencies. The benefits of single sensor acquisition were clear, but conventional technology was not sufficiently advanced to realize the objective. Q-Marine breaks this barrier by delivering the next generation of hardware and processing capabilities.

Acquisition for accuracy

Q-Marine uses digital group forming to process single hydrophone signals. This eliminates compromises that must be made when designing analog groups in conventional streamers in order to meet specific survey objectives; for example, to reduce anticipated noise or illuminate a chosen target.

By selecting sensor groups after acquisition, digital group forming achieves superior filtering. The advantage: processing parameters can be changed to impose different spatial filters at will.

The availability of Q-Marine single-sensor data opens up many other digital signal processing opportunities. Signal distortion due to the movement of hydrophones with the survey vessel, which can exceed a normal group length



This near trace example compares data before (left) and after shot-to-shot deconvolution using the proprietary Calibrated Marine Source (CMS.) After CMS deconvolution (right), the variable bubble energy is successfully attenuated and the reflector continuity is improved. For 3D, and especially 4D, variations in source signature may be measured and corrected with the CMS for consistent and repeatable results.

This survey was conducted for Statoil (with partners Norsk Hydro, Norsk Agip, and Enterprise Oil Norge), Norway license PL258

during the 'listening' period, can be corrected. Adaptive noise-reduction algorithms applied to the digital signals can significantly reduce spurious and environmental noise while preserving signal amplitudes.

Dense data, fast data

Q-Marine provides the extremely dense spatial sampling needed for the highest resolution seismic surveys:

- Latest advances in fiber-optic communications allow Q-Marine systems to acquire up to 80,000 channels. This equates to more than 4,000 hydrophones per streamer and up to 20 streamers.
- Advances in onboard processing enable the real-time signal preprocessing, data quality analysis, digital group forming, and stacking that are at the heart of Q-Marine processing.
- Dense inline sampling is complemented by patented Q-Fin* streamer steering devices that allow streamers to be accurately controlled at separations of as little as 25m.