WesternGeco

Seeing Below the Surface

It is widely agreed throughout the exploration and production (E&P) industry that seismic technology has contributed most to increasing the success of hydrocarbon exploration programs during the past two decades.

In the 1970s, the drilling success rate was about 10%, but this figure had risen to 32% by the 1990s. This increase is primarily due to the accuracy and clarity that 3-D provides. Shell was one of the first operators to realize the value of 3-D seismic technology and has since pioneered a variety of new applications in the pursuit of continuous improvement in quality and efficiency.

WesternGeco has worked with Shell to provide the technology for many innovative techniques, including the acquisition during the 1980s of 3-D data over huge areas offshore The Netherlands using a highly efficient "Quad-Quad" geometry. This technique involved two vessels, each equipped with two seismic sources and multiple streamers. WesternGeco continues to supply much of the seismic information required for Shell's interpretation, exploration and development projects.

Recent WesternGeco 3-D marine seismic acquisition projects for Shell include an assignment for the *Geco Emerald* for Shell Malaysia offshore Sabah; a 3-D survey by the *Geco Eagle* offshore Sarawak, also in Malaysia; and an east coast Canada 3-D survey by the *Western Monarch*.

On land, WesternGeco has been continuously acquiring 3-D seismic surveys for Petroleum Development Oman (PDO) for several years. Last year, WesternGeco conducted eight land-based 3-D seismic assignments with Shell in Canada and is involved with a Shell project onshore New Zealand.

The WesternGeco Seismic Reservoir Services (SRS) group provided a number of services on Shell projects, including reservoir characterization using EarthGM*, WesternGeco's geostatistical modeling software, for studies with PDO and a 3-D acoustic inversion study for Shell Venezuela.

"Our partnership with WesternGeco in managing seismic data processing has facilitated us delivering a quality product that meets the demand of our oil and gas business," said Don Spillman, manager of seismic technology for Shell Exploration and Development Co.

The* Western Monarch *performs 3-D surveys off the east coast of Canada.

As 3-D seismic technology has become widespread, quality also has improved, partly because of finer spatial sampling and more accurate acquisition systems, but largely as a result of better processing technologies. Seismic acquisition records data sampled in the time domain, typically at 2-millisecond or 4-millisecond intervals between 6 seconds and 12 seconds. Most data processing also is performed in the time domain, as are the data volumes ultimately delivered for structural and stratigraphic interpretation, combined with downhole geophysical and geological information. Time domain imaging is based on a variety of assumptions that break down and lead to positioning errors and uncertainties in the presence of complex structures, such as those found in and around salt bodies, to which many of the world's most prospective hydrocarbon reservoirs are related.

WesternGeco has led the seismic services industry in delivering migration in the depth domain; placing reflections in their correct location to optimally focus the 3-D seismic image. New depth migration processes, applied earlier in the overall processing sequence, not only produce images in which the drill bit can be directly located, but also provide much clearer images in very structurally complex environments. WesternGeco has delivered depth migrated 3-D volumes covering nearly 39,000 sq miles (100,000 sq km) over complex areas, such as the Southern North Sea and Gulf of Mexico. Recent depth imaging projects for Shell include the **Mars** and **Ursa** areas of the Mississippi Canyon where a 46-block final volume report was completed in 37 days and the **Princess** project, completed in 3 weeks. Several other Shell projects that include depth imaging are ongoing throughout various locations in the Gulf of Mexico.

Most land seismic systems and all towed streamer marine systems record only pressure (P) waves. In most circumstances, these provide excellent images; however, in some geological situations, P-wave imaging is inadequate – gas-filled sediments absorb and distort P-wave energy, masking reflections from underlying strata. To achieve accurate imaging in such situations requires the recording of multicomponent data, which provides shear (S) wave data in addition to P-waves. Shear waves are unaffected by pore fill, so can image beneath gas clouds. The combination of P- and S-wave data also can often resolve uncertainties about lithology and provide an indication of pore fluids, distinguishing among oil, water and gas. Shear waves do not travel through liquids, so marine surveys are recorded using an ocean bottom cable (OBC) containing hydrophones and groups of three orthogonally mounted geophones, providing four component (4C) data. WesternGeco has provided Shell with the acquisition and processing and analysis on a number of recent OBC projects including the U.K. North Sea Brent survey, and 4C surveys in the South Timbalier and Main Pass/High Island areas of the Gulf of Mexico.

Recovery rates of known oil-in-place are commonly only one-third and seldom more than one-half. Factors contributing to this inefficient recovery include non-optimum positioning of producing and injector wells and premature water break-through due to inaccurate knowledge of reservoir pore fill and flow.

Four-dimensional time-lapse seismic can map fluid movement and the gas-oil contact/oil-water contact; track pore fluid saturation changes; identify flow units, flow barriers, by-passed oil and in-fill drilling opportunities; and monitor the performance of enhanced recovery programs. The 4-D method involves the accurate measurement of changes in the seismic response of a reservoir due to the extraction and movement of hydrocarbons during time. These changes are usually extremely subtle and can easily be masked by various types of noise inherent to conventional seismic methods. To address this problem, WesternGeco has developed a new system that takes seismic imaging to a new level of quality and accuracy. This engineering project – the largest in the company's history – was launched in the mid-1990s to provide a revolutionary new technology for land and marine environments. The result, simply called Q*, has been applied to onshore and offshore surface seismic. The offshore implementation is called Q-Marine*.

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Q-Marine addresses the critical perturbations in the marine acquisition system that introduces noise into the seismic data. These perturbations come from wave and swell noise, positional errors, and variations in the seismic source and in the recording equipment. Q-Marine can record the signals from up to 80,000 individual hydrophones, requiring data rates in excess of 20 MB per second, made possible by advances in electronics and fiber-optic networks. Each hydrophone is of a new tubular design, individually calibrated to produce high-fidelity responses and preserve the received signal amplitude. The system supports more than 4,000 hydrophones per streamer and up to 20 streamers. This very high channel single-sensor capability not only ensures the seismic wavefield is adequately sampled, but also properly records the noise, which is attenuated using adaptive software techniques that are much more effective than the analog methods of conventional systems.

Single-sensor seismic technology has long been a goal because of its promise to record a wavefield that could be unambiguously reconstructed at any place and any time. Shell's Leo Onkiehong and others first envisioned it in the late 1980s. As cited early on by Onkiehong, while *"a recording system with a separate channel for each geophone is still the comprehensive solution…it will require another step in hardware development and data processing price reduction."* With Q, this is now a reality. ✣

* *Mark of WesternGeco*