The Sub-Salt Imaging Challenge

Throughout the world, sub-salt imaging remains a major issue. Service and oil companies are striving to meet this challenge.


Photo: Haflan Carstens

Steve McIntosh, Regional Sales and Marketing Director of Fairfield Industries.


Photo: Jane Whaley

James Keggin, Seismic Quality and Technology Manager for BP Egypt. James and Steve are among the many dedicated and innovative people who have seen that progress in wide and multi-azimuth seismic technology has resulted in impressive enhancement of sub-salt seismic imaging.

Jane Whaley

Like many major oil companies, BP has been investigating different ways of solving the sub-salt imaging predicament, particularly in the Nile Delta and the Gulf of Mexico. Working in conjunction with seismic companies, much of the research has concentrated on alternative ways of receiving the seismic returns, moving away from the linear architecture used in the traditional seismic survey.

Looking under the table

"Exploration in the offshore Nile Delta has concentrated on the prolific Pliocene channel play, which lies above the salt and gives us excellent images," explains James Keggin, Seismic Quality and Technology Manager for BP Egypt.

"However, beneath this there is a regionally extensive, thin layer of Late Miocene anhydrite, interbedded with other material, which sits about 3km below the seabed and effectively masks the deeper horizons from seismic investigation. Some of us think there is a prize down there, but trying to see through the salt is like trying to see through the textured glass of a bathroom window, as it distorts the acoustic returns and makes it difficult to get an accurate picture of the geology below."

Traditional 2D seismic uses a sound source and multiple sensors towed behind a seismic boat, recording signals reflected back from the subsurface, which, as James explains, "builds up an image in one direction like a single page from a book."

"Conventional 3D seismic extends this by combining many 2D images in the same way so that the pages of paper combine to make a cube. We are now broadening this idea by looking at the same part of the seafloor from many different angles or azimuths, with up to six conventional 3D surveys recorded in different directions in quick succession. These are then processed separately and the data is combined to give a much clearer and more accurate picture of our reservoirs."

"It's a bit like trying to see under a table. If you look at it from only one angle you cannot see the whole picture, so what we are doing is repeating the experiment from different angles," says James.

A world first

The concept of multi-azimuth seismic (MAZ) has been recognised for a long time, but although it has been done for many years on land using stationary receivers, it has only recently been considered to be economically feasible in a deep water marine setting.

"Only one vessel is required, and even if we survey an area six times, the economy of scale and shared mobilisation costs mean that it is not six times as expensive," explains James.

"Our first multi-azimuth survey, working with PGS, was an appraisal of the Raven Field, in the western Nile Delta," James says. "This was a world first and we have been delighted with the results. We had previously identified channel systems in the reservoir area, but we could not delineate them clearly enough to confidently place appraisal and development wells. Our six-fold multi-azimuth survey, undertaken in late 2004, has given us a far clearer image of the reservoir. Economically, the extra seismic costs are easily countered by the savings made through more informed and successful well placement."

BP has been so satisfied with the results in the Raven Field that they have now commissioned a new 'Mega-MAZ' survey to look at further sub-salt exploration targets in the offshore Nile Delta. As James says, "We believe in the offshore sub-salt potential, so multi-azimuth surveying is a vital tool in our exploration efforts."

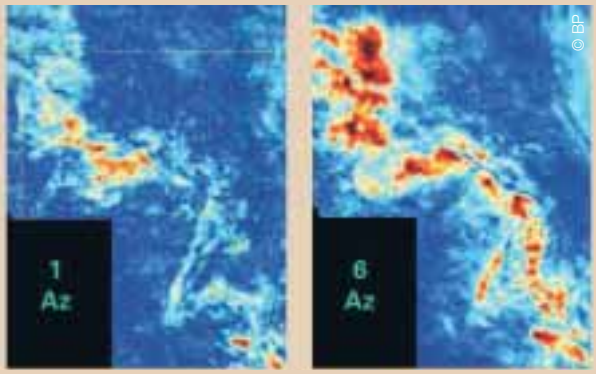
Wide Azimuth

While multi-azimuth seismic has proved successful in the Nile Delta, it is not necessarily the key to sub-salt imaging in the Gulf of Mexico. Here the challenges are different, as the mobile salt horizon results in variations in wavelength and thicker bodi-

es, causing severe imaging problems below salt. Tim Summers, Sub-Salt Imaging Technology Director for BP, takes up the story.

"In the Gulf of Mexico we first tried several azimuths of seismic to visualise these large salt bodies. When that showed promise, we moved on to wide azimuth towed streamer seismic, or WATS, to maximise the number of azimuths in a single survey. This is a multi-vessel operation, using a streamer boat and dual source vessels offset laterally. Sources are fired sequentially and the sensors receive data from each in turn, giving us data from many different azimuths. This gains us a much clearer image of the salt bodies and what lies beneath it."

The first WATS survey was completed in early 2005 for BP by Veritas over the Mad Dog Field in the Gulf of Mexico. The early results proved successful and resulted in plans for further work over other BP operated fields in the deep water Gulf during the second half of 2006. Tim adds that "while the application of WATS were performed on appraisal and development projects, we fully anticipate extending the technique into exploration, applying it over large areas to reduce risk on the increasingly complex subsalt prospects'.

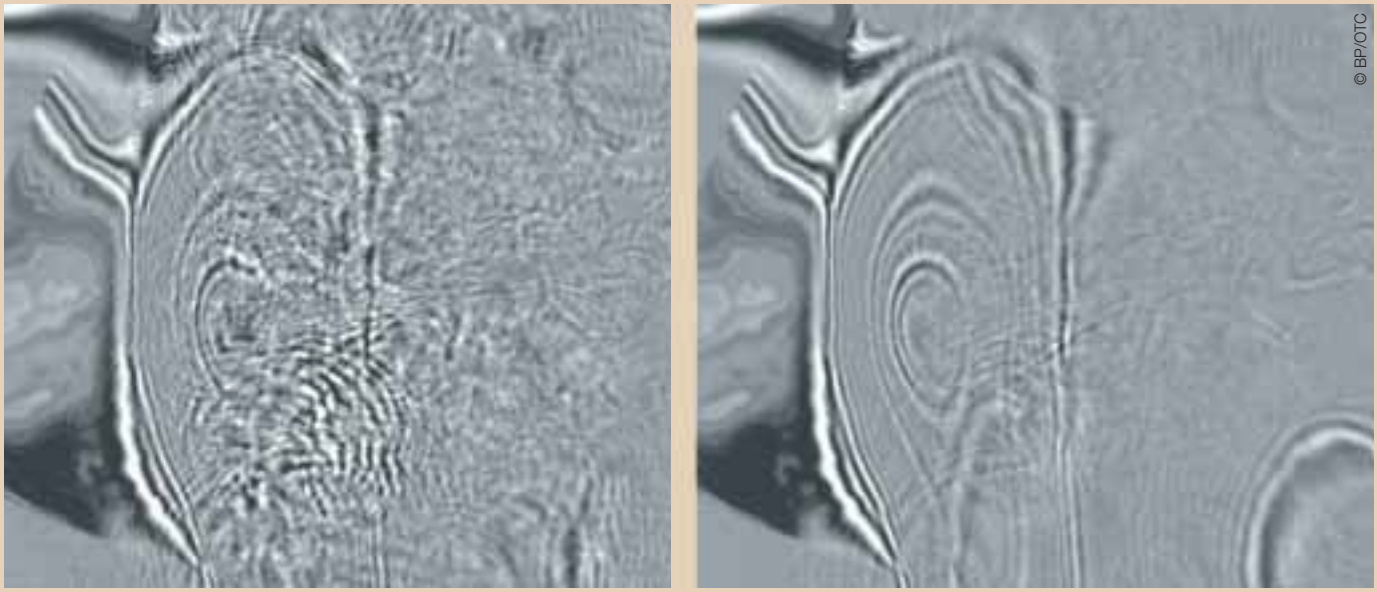


The six-azimuth stack process produces a much more reliable image of the deep reservoir system in the offshore Nile Delta.

Imaging deep water fields

Ocean bottom cable surveys, where the sensors are laid on the seafloor rather than towed, have also proved very effective in acquiring wide azimuth surveys. In deep water, however, they have limited operational depths and are very expensive to deploy and position, requiring two dynamically positioned cable vessels as well as a sound source ship. They are also not so effective in areas where the seabed topography is rugged or heavily obstructed by infrastructure.

Fairfield Industries have an alternative system, Z-3000, for conducting wide azimuth surveys using sensors or 'nodes' laid individually on the seabed. Steve McIntosh, Regional Sales and Marketing Director of Fairfield Industries, explains the technique. "The Z-3000 system consists of a series of sensors deployed individually on the seafloor, operating completely independently with no inter-connecting cables. The nodes record data continuously from deployment



Comparison of single and six-azimuth seismic depth slice from the Gulf of Mexico.

to retrieval and can measure both compressional and shear waves, working in water depths up to 3,000 metres. Each node is positioned using GPS and a remote controlled vehicle (ROV) to any desired receiver geometry, while the source vessel sails a conventional grid, effectively undertaking a multi-azimuth survey. At the end of the data acquisition sequence the nodes are retrieved onboard the mother vessel, where the data is downloaded, quality controlled and the batteries recharged, ready for re-deployment."

As Steve says "while Fairfield Industries was developing nodes for shallow water, BP was actively seeking ways to image under and around the salt in deep water. In 2004 BP commissioned Fairfield to manufacture deep-water sensors and acquire the industry's first large-scale deep water node survey, starting in October 2005 and completed in March this year. Over 900 sensors were deployed on the Atlantis Field, in the Gulf of Mexico, in water depths between 1,400 and 2,200m.

BP and Fairfield have been equally satisfied with the project from both the acquisition and the operational side. For Fairfield Industries, Steve McIntosh says "the system proved to be both efficient and reliable. This initial survey proved that we can effectively operate in a deep water environment with highly variable complex water bottom and acquire data at the field scale. From a commercial standpoint, only one receiver handling vessel is required, reducing operational costs."

Successful Results

BP is still processing the data from the Atlantis Field survey and are encouraged by the results so far. "This is a very effective and efficient method of acquiring wide-azimuth seismic in deep water in extremely challenging environments," Tim explains. "The nodes acquire shear waves in addition to the P-waves, which will enable us to illuminate and define reservoir properties for a broad range of subsurface challenges."

BP, in conjunction with their various partners in the industry, have already come up with a number of innovative and successful ways of seeing the horizons and potential hydrocarbon accumulations below the ubiquitous salt in many parts of the world. As Tim Summers says, "We have extended the principles learned from ocean bottom cable surveys to provide wide and multi-azimuth seismic solutions for deep water. We are developing these different techniques so that we have a variety of options, meaning that we can choose the most appropriate application for the circumstances. One size doesn't fit all; we need to use the acquisition solution that suits the subsurface challenge, the operating environment and position on the value chain from exploration to production."

Who knows, in a few years time, salt may not be considered a barrier to successful exploration and production at all?

The Z-3000 nodes technique uses an array of seabed seismographs to collect different types of waves reflected from the subsurface.