

# New seismic technologies for deepwater success

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Deepwater drilling continues to be expensive, yet the prize remains both elusive and massive. Many of today's exploration targets lie in the later Mesozoic and Tertiary extensional regimes when vast amounts of salt were deposited, and whether this is highly mobilised such as in the Gulf of Mexico, or mostly still in situ such as offshore Brazil, it presents significant issues and technical challenges. Indeed, the costs associated with addressing many of these have been sufficient to cause a temporary halt in new activity planning when commodity prices fell dramatically in early 2009, but with stabilisation beginning to return, interest is beginning to pick up once again.

Without doubt, the risk of drilling and completing a deepwater well successfully represents a serious challenge to the technology and ingenuity of exploration and production (E&P) companies as well as to the service companies involved. Among the operators, Petrobras has been particularly successful in developing the needed processes as the successes of the Santos basin so clearly demonstrate.

In both sub-salt and pre-salt deepwater prospects, the technical challenges begin with the identification of the potential reservoir. In many ways, the mobilised salt trend in the Gulf of Mexico represents the most extreme geophysical challenge in the world where the problem is to find a way of seeing beneath salt structures that themselves are highly complex. Either energy must be transmitted through the salt and back again, or novel ways of focusing energy around the salt must be found. As most of the energy gets reflected by the top and does not

even penetrate the salt the usual approach is to look round the salt in a technique known as wide-azimuth 3D.

This has become the established norm in the Gulf of Mexico and a quick look at multiclient data licenses in this area since 2008 shows that more than two thirds of these sales are associated with wide-azimuth surveys despite the wide availability of newly depth-imaged narrow azimuth data. The message is clear; when it comes to risk reduction, E&P operators do scale down, but aren't willing to trade down.

Indeed as targets become more complex, survey techniques evolve to provide evermore complete coverage, or illumination, of the potential reservoir. One of the latest methods is known as coil shooting where the acquisition seismic vessel steams in a series of overlapping circles thereby constantly varying the azimuth. This has already been proven to provide both better illumination, and significantly lower cost, than wide azimuth, and can be achieved with a single vessel. Yet even this very recent technique has now developed further to a double coil, or helix pattern with the objective of finally unlocking the secrets of the most complicated and thickest salt structures in the Western Gulf of Mexico. Such surveys are also rendered more efficient through the use of the latest-generation seismic vessels that provide improved transit speeds, lower power consumption, reduced emissions and lower levels of pitching and vibration for a friendlier work environment.

In the highly attractive deepwater blocks offshore Brazil, sedimentary salt cannot be avoided. Where it is unevenly deposited, wide-azimuth and coil-shooting patterns will clearly help. However, the main challenge is getting sufficient detail of the shape of the salt to enable proper depth imaging and then ensuring that sufficient energy be available to illuminate the pre-salt section. The final challenge is then to do the best job possible in inverting from seismic data to geology given the paucity of well control.

Traditionally, this is constrained by well data, and it is always improved when calibrated by such information. However, seismic data typically has a gap in its frequency content, which means that it cannot be inverted reliably in the absence of reasonably dense well data. This is very much a Catch-22 situation – to decide where best to place highly expensive wells a reliable inversion is needed, but to make that inversion, a number of wells are needed in the first place.

Technology helps again. To increase the confidence in using seismic for deepwater reservoir characterisation with limited well control, a way must be found to add valid data at the bottom of the spectrum preferably as low as 2 or 3 hertz, which fill

Coil-shooting technology combines the WesternGeco advantages of single-sensor acquisition, streamer steering and dynamic control experience to shoot in a continuous turn





the gap and allow confident extrapolation a long way away from the well. New DISCover\* technology, which involves some seismic streamers towed more deeply – to provide the vital low-frequency content – is yet another example of the way seismic experts are finding new approaches to long-established problems using the unique WesternGeco Q-Technology\* single-sensor platform.

### New applications and new products will be needed in order to fully realise the potential of Brazil's pre-salt resources

There is, however, one major unknown where seismic signals do not provide a clear answer; what type of fluid is in the reservoir? Borehole-based resistivity – the very first measurement developed by Schlumberger in the 1920s – has long been recognised as a good hydrocarbon indicator because oil-bearing formations exhibit higher resistivities than those that are water-filled. A much larger-scale measurement of the same type, controlled source electromagnetic (CSEM), is now available and acts as a valuable complement to seismic.

It is worth looking at the workflow required to integrate such different measurements as this illustrates the complexity and opportunity offered by frontier exploration. In a typical case the original seismic would have been acquired earlier, perhaps as part of a regional programme. Given the structural complexity of the new areas, as well as the presence of sedimentary salt, a significant investment in depth imaging would be required. Once the seismic has been properly focused and placed in depth, satellite imagery and hydrocarbon seep analysis is added. The integrated information is then loaded into the Petrel\* workflow process software and the resulting interpretation analysed by creating a geological history that evaluates hydrocarbon charge, maturation and eventual migration. This, combined with the structural setting, generates several potential prospects, and it is these prospects that are then subjected to CSEM survey to permit an estimate of the fluid type present.

This workflow, enabled by complementary measurements and a collaborative and multidisciplinary workflow sharing a common software platform, is just one example of how our industry is breaking down barriers—barriers that we can no longer afford whether they exist between team members, across disciplines, or between service providers and operating companies.

Some challenges still remain – today's CSEM measurements are relatively cumbersome, with signal-

to-noise levels such that fluid identification below very thick salt is a way off. However, experience is growing and WesternGeco has already completed a multiclient project in the Potiguar Basin, offshore Brazil covering 1300 sq km. Among other geophysical techniques, the change from narrow to wide-azimuth 3D seismic, well established in the Gulf of Mexico, adds value but is little used elsewhere. But the advances in depth imaging, which are extremely computer intensive, are growing rapidly internationally with the algorithms used increasing the computer effort demanded by several orders of magnitude.

I began this story by mentioning both Petrobras' contribution to deepwater exploration, and the continued high cost of drilling such wells. Clearly, the service industry must pursue its efforts in developing the technology needed to mitigate the risk associated with placing those wells. As the excitement over pre-salt resources leads to the realisation that the development work needed will be immense, it becomes clear that using existing technology in new applications while developing new products to fill the gaps that remain is essential. I believe that part of the solution to this lies in targeted research and engineering efforts focused on specific issues and operated closely with key customers. At Schlumberger, we are already doing this in a number of facilities in Abu Dhabi, Calgary, Dhahran, Kuala Lumpur, Moscow and now Rio de Janeiro. It is an extremely efficient way to address the significant challenges that remain as we come to rely on ever-smaller pockets of oil, trapped in ever deeper and more complex reservoirs. □

\* Mark of Schlumberger

Integration of technologies within the Petrel workflow process enables clear visualisation of hydrocarbon reservoirs

