CSEM Continues to Stride Forward

For the last few years, the most talked about technology in the hydrocarbon exploration industry has undoubtedly been Controlled Source Electromagnetic imaging, but what does the future hold for this important development?

Jane Whaley, Associate Editor

Controlled Source Electromagnetic imaging, or CSEM, is probably the most important new technology in the field of offshore oil & gas exploration since the advent of 3D seismic some twenty years ago (GEO ExPro 01/2004; 05/2005, 04/2007). However, it still faces challenges on both technological and industry acceptance fronts, according to Andy Overton of Offshore Hydrocarbon Mapping plc (OHM), one of only a handful of companies in the forefront of this new technology.

"We have a surprisingly conservative industry," he explains. "In spite of the rapid strides made with this new technology, there are still many sceptics out there. This is compounded by the fact that companies that have found the technology useful are understandably reluctant to release too much data in the form of case studies, so it is quite hard to provide the evidence. Among some, however, there is the contrasting perception that CSEM is the answer to everything, which sets very high expectations. In fact, it is only one of the answers, but when combined with other technologies like seismic it can greatly enhance our understanding of what is below the seafloor."

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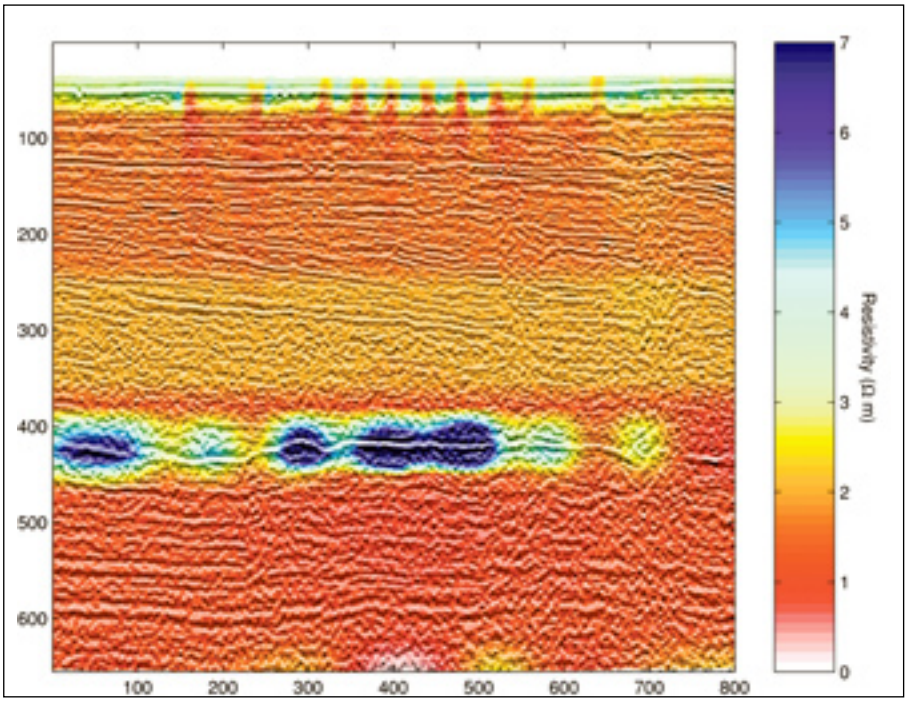

Comparison of resistivity section derived from CSEM data with the coincident seismic data (courtesy of TGS-Nopec). The resistivity anomaly derived from the CSEM survey is coincident with the known position of the reservoir.

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Measuring seabed resisitivity

The properties and potential of electromag-

The transmitting dipole, seen here being retrieved from the seabed offshore Equatorial Guinea, emits a low-frequency electromagnetic signal that propagates into the water column and downward into the subsurface.

netics have been known since the 1980's, but commercialisation really only started at the turn of the century, with a major 'proof of concept' cruise in 2000. "On board that ship were researchers from Statoil, University of Southampton, and Scripps Institute of Technology, all of whom had been researching different aspects of the technology," Andy describes. "The success of the trip meant that a number of CSEM companies were formed, including OHM, which in 2002 was a spin-out from Southampton University." Like other EM companies, OHM grew rapidly, and was floated on AIM (a market operated by the London Stock Exchange) in 2004. The company estimates that it has already undertaken more than 150 CSEM surveys and interpretation projects, spread over five continents.

So how exactly does CSEM work? "It tells you about the resistive properties of the earth," Andy explains. "CSEM is based on a low-frequency electromagnetic signal coming from a towed source which is transmitted through the seafloor to an array of multicomponent electromagnetic receivers placed on the seabed. Since the direct signal through the water is rapidly attenuated, the signals arriving at the receiver are dominated by fields that have interacted with the earth, so the bulk electrical resistivity of the subsurface can be determined. This resistivity is modified by the presence of subsurface resistive layers, and because hydrocarbons increase the resistivity of a formation by 1 to 2 orders of magnitude, these changes can be detected and logged by the receivers. A CSEM survey can therefore indicate the presence of oil and gas in an offshore reservoir, and also help outline the edges of an accumulation.

"When this is combined with the structural information found by seismic," Andy continues, "we have most of the data we need to understand what lies beneath the seafloor. It's a 1 + 1 = 3 scenario. That is why we have recently seen the integration of seismic and EM companies, with PGS buying the small Edinburgh based company MTEM (GEO ExPro 04/2007), while CGGVeritas have taken a 15% stake in us at OHM (GEO ExPro 04/2007)."

CSEM can therefore indicate the presence of oil and gas

CSEM clarifies North Sea Gas Field

The recent purchase of Rock Solid Images (GEO ExPro 05/2007), a specialist data analysis and well log integration company, coupled with the seismic capacity of CGGVeritas, allows OHM to offer a wide range of services to the oil industry. "Our aim is to deliver a complete package to our clients, from feasibility study and survey planning to a final set of valuable and informative deliverables." says Andy. "It is important to be involved at the planning stage of a survey, as this technology is extremely parameter sensitive and surveys have to be carefully tailored. The choice of transmission frequency, for example, is critical to survey success. The old adage 'garbage in, garbage out' still holds true, so it is important to get the design and modelling aspects correct in the first place, to ensure the optimum final result."

OHM recently undertook a CSEM survey on the Nuggets-1 gas field in the North Sea, which ably demonstrates the significance of this integrated approach. Initial results, using the simplest inversion processes, clearly suggested the resistive presence of hydrocarbons, as expected from

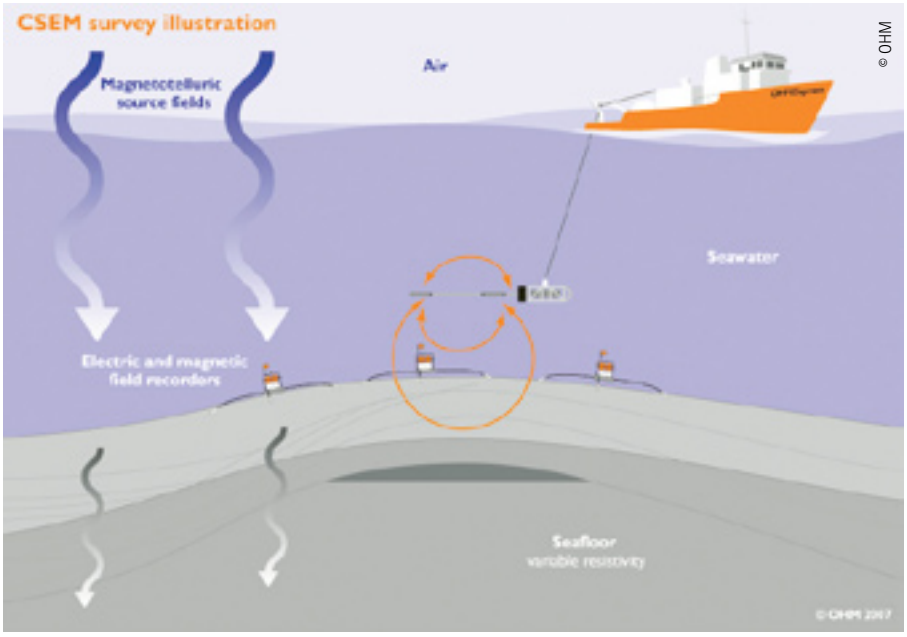
seismic investigations. However, when more advanced techniques were applied to the CSEM data, they showed that the initial values for depth and true resistivity of the reservoir had been underestimated. Using structural information from seismic data, and adding additional information on the geoelectric background from CSEM receivers off-target, the resolution of both the lateral extent of the reservoir and the resistivity within it increased dramatically. Final results agree well with the resistivity of the gas reservoir measured through well-log data.

The Nuggets-1 case study clearly illustrates that a reserves-in-place estimate from integrated CSEM and seismic data offers greater reliability than could be obtained from either type of data alone," says Andy.

New directions

It is possible to measure resistivity changes to a depth of as much as 4,000m below the seabed, but for some years the use of CSEM was limited by the fact that it could only be used in water depths greater than 1,000m. In shallow water, signals interact with air, which is extremely resistive, creating noise. This is known as the 'airwave effect', and dominates the CSEM response at the receiver, restricting the sensitivity of the method at depth. The EM industry has been working to extend the operating range of the technology into progressively shallower water by researching the physics behind the airwave phenomenon, and inputting this knowledge into survey design, data acquisition and processing.

Multi component receiver is seen being deployed from the survey vessel.



The CSEM method uses a high-powered horizontal electric dipole source to transmit signals to an array of seafloor receivers that detect and record the electric and/or magnetic field at the seafloor. The resulting data can be interpreted using a combination of forward modelling, geophysical inversion and imaging to determine the resistivity structure of the underlying seafloor to depths of several kilometres.

"By early 2005 we could work in depths of 300m," Andy continues "but the Nuggets-1 survey in 2007 showed to us that the CSEM method can be applied in water depths of less than 130m, and we now operate in less than 50m of water. By extending the operating envelope into shallow water, the range of potential exploration and appraisal targets has been dramatically increased."

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"At the moment CSEM is primarily an exploration tool, but with further research and investment it will soon become a valuable technology in the field of reservoir exploitation design and engineering. Exciting progress is being made in integrating seismic and CSEM, not as images of the earth, but as fundamental measurements of the earth's properties."

"In research we are seeing clear evidence that this careful integration can yield quantitative and accurate surface made measurements of rock and fluid properties like porosity and hydrocarbon saturation. This will open up new markets for the technique in reservoir management, creating considerable scope for its use in life-of-field monitoring and the investigation of remaining reserves in apparently depleted fields. At the moment we understand the science of how to do this using CSEM, but it will require quite a lot of development in terms of the application hardware. However, we expect it to prove of huge benefit to oil companies looking to maximise the value of their investments in fields."

The technology and market surrounding controlled source electromagnetics has grown fast, but the industry confidently expects this field to continue to expand rapidly and in a number of new directions in the future.