Electromagnetic Scanning Drives Innovative Technology and Business Models

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Summary/Introduction

Just two years ago, the term electromagnetic (EM) scanning was virtually unknown. Today, several major oil companies, along with leading independents and nationals, are using the technique to accelerate the exploration of frontier basins and search mature basins for missed opportunities.

Scanning is a new application of seabed logging and relies on the same physics. Elligsrud et al. [1] and Eidesmo et al. [2] discussed that rocks in which the pore spaces contain significant accumulations of hydrocarbons typically exhibit higher resistivities than those with brine-filled pore spaces. Seabed logging is a method of measuring subsurface resistivity before drilling. These measurements can be integrated with other geoscience data to enable more reliable estimation of reservoir fluids. Initially, seabed-logging surveys were designed to investigate structures identified from seismic data to give operators increased confidence about the probability of finding hydrocarbons and their extent (Figure 1).

Although scanning uses the same measurement techniques, it is driven by a different objective. Scanning is used over wide areas where the purpose is to find new reservoirs rather than testing the resistivity of structures identified from seismic data. Scanning can be applied early in the frontier exploration process, often in areas with only 2D seismic data available. However, it can also be used later in the exploration process to test and delineate multiple prospects and identify additional leads in highly prospective areas. It can even be used late in a field’s life cycle to identify missed opportunities in mature basins.

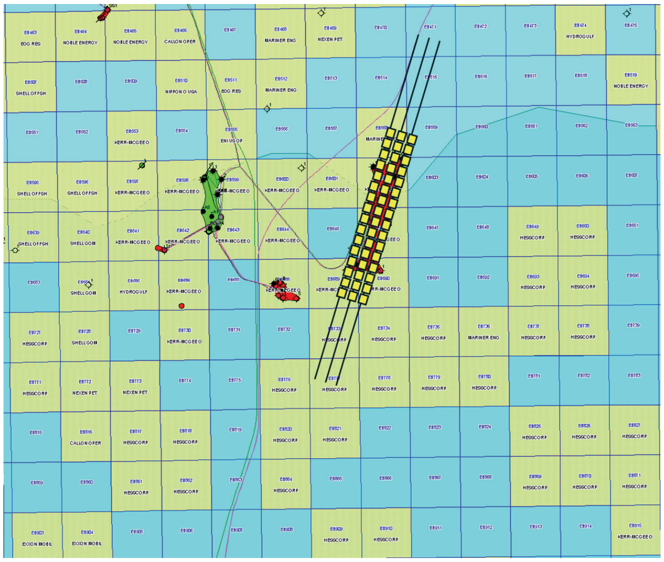

Figure 1: Target-oriented seabed-logging surveys use densely sampled mini-grids to delineate reservoirs and provide accurate reservoir-depth and pore-fluid information.

The key differences between scanning and conventional seabed logging are scale and sampling. Since the goal is to find new prospects, large areas must be covered (Figure 2). Target-oriented seabed-logging surveys cover an area of only a few hundred square kilometres, but scanning surveys usually take in several thousand square kilometres. Projects covering over 30,000 km^2 are now being evaluated. To enable surveys of this scale to be acquired efficiently, sampling is sparser than for target-oriented surveys. These changes in scale and sampling are driving radical changes in seabed-logging technology, together with its business models.

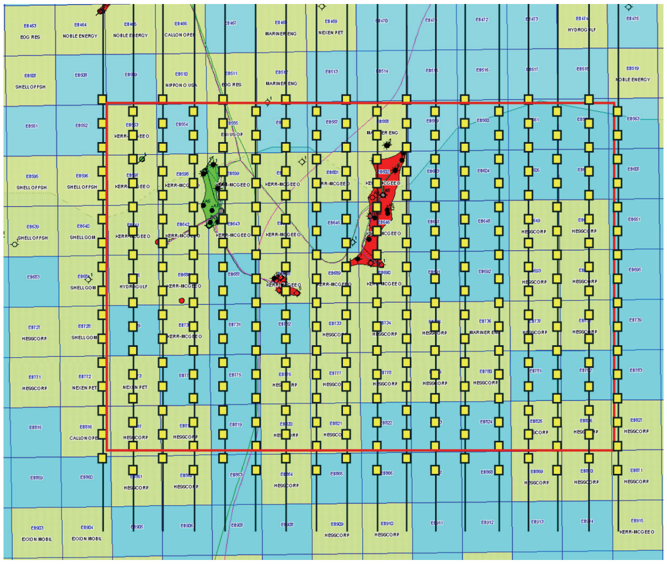

Figure 2: Large (often multiclient) EM scanning projects use sparse design and wide azimuth acquisition to enable rapid and cost-effective detection of hydrocarbon. See Ridyard et al.[3] for more details.

Larger Surveys Drive Multiclient Business Models

In the late 1980s and early 1990s, 3D seismic technology revolutionised exploration. The novel 3D view of geology was a key factor in this change, but equally important was a dramatic shift from small proprietary surveys to large regional ones. The same factors are in play with EM scanning. The first square kilometre of a scanning survey may cost several million euros to acquire because a vessel must be mobilised to the area and a significant partially imaged area must be acquired – analogous to the need to acquire a full migration aperture for 3D seismic surveys. The next square kilometre might cost 1000 times less. Therefore, it is clear that large surveys are far more efficient than small ones. In those areas of the world where block sizes are small (<2000 km^2), this usually means that operators must collaborate in some way to acquire data cost-effectively. This could be as fully pre-committed "group scans" or truly speculative multiclient projects.

New Measurements Require New Thinking

In some of the world's more remote and underexplored basins, governments are also looking at EM scanning as a way to stimulate new thinking and attract operators back to areas where conventional exploration approaches have failed to identify successful play fairway models.

In more mature basins like the Norwegian Sea, several innovative small operators, such as Aker Oil & Gas Technology and Rocksource, are using EM scanning as a central plank in their business models. Scanning is being used to identify prospective new acreage before licensing and to find new fields in older, often relinquished, properties.

Survey Design: A New Technique

Designing target-oriented seabed-logging surveys involves detailed analysis and modelling of structures and careful placement of individual receivers and source lines to optimise the imaging of a specific target. For scanning, things are different. The design must be sufficient for a range of targets and is usually based on regular sampling of the volume under investigation.

Seabed-logging receivers can be placed in a variety of acquisition geometries (for example, parallel, orthogonal or staggered grids), and designing the optimum survey pattern can be time-consuming.

To address this challenge, a new technique known as grid modelling has been developed. The first step in grid modelling is similar to that in traditional seabed-logging survey modelling: a 3D subsurface resistivity model is constructed. A dense grid of sources and receivers is modelled over the entire area. This modelling process, described by Maaø et al. [4], is very computer intensive, but, once the computations are complete, the database of modelled responses created can be used to enable rapid extraction of any possible combination of source location, source orientation and receiver location. This process was described in detail by Thrane et al. [5]. A pre-modelled input grid density of around 100 m offers extraction of interpolated model data with errors that are well within acceptable tolerances.

This approach means that a large number of survey-design parameters can be varied and the responses evaluated. Parameters such as survey position and orientation, and source and receiver spacing can be quickly tested to ensure that the optimum survey design is developed.

Survey Design: A Fresh Approach

The goal of conventional seabed-logging survey design is to ensure that any target that might be present is detected. This is also true for some scanning surveys, particularly in mature basins, where subsurface structures and resistivity are well understood. However, in frontier areas it is likely that the area under investigation is not well understood and has limited 3D seismic data and well control.

In these circumstances, the survey design requires a rethink of the basic philosophy. Instead of asking whether the survey will detect a predefined target, the question becomes “What survey design is required to detect the minimum commercially viable reservoir in the area?” Thus, in a remote, deepwater application with limited production facilities, the threshold for commerciality may be much higher than the threshold in a more-mature shallow-water area. Therefore, the survey design can be based on the detection of a reservoir with a size and shape close to the “commerciality threshold” for the area. The parameters of this threshold reservoir then drive the survey design parameters, notably the cost-critical source and receiver spacing. Other parameters such as source line orientation are driven by the predominant geologic trends and the area’s play types.

Data Acquisition Geometry

The goal of data acquisition is to supply sufficient data to detect all commercial reservoirs for the minimum cost and time. It has already been noted that the survey geometry should make use of the receivers around the source to provide the finest possible sampling of all azimuths and offsets. The ideal geometry for imaging would be to tow orthogonal source lines over a square of receivers with a minimum spacing equal to the longest useful offset – typically around 15 km. However, in most cases, adequate subsurface detection can be accomplished with only a single towing direction.

For a dipole source, the required grid of receivers is longer than it is wide (Figure 3). This is because, as described by Maaø et al. [6], a dipole source delivers usable energy into the subsurface in a cone approximately 45° ahead and behind the direction of the tow line, with little usable broadside energy being radiated. This data acquisition geometry acquires a broad range of offsets and azimuths throughout the data volume, and facilitates efficient acquisition because it is quite easy to “roll” this spread across large areas in a manner similar to 3D-seismic survey acquisition on land.

A New Scale of Data Acquisition

The arrival of custom-designed, multi-streamer vessels helped to trigger the 1980s explosion in the use of 3D seismic surveys. Similar forces are at work in the EM scanning industry.

It would require 60 receivers in 3 active rows of 20 to efficiently image a square area of 3600 km^2 using 3 × 3 km sampling. However, if the sample interval were reduced to 2 × 2 km – a spacing that might enable more sophisticated processing and inversion – each line would require 30 receivers.

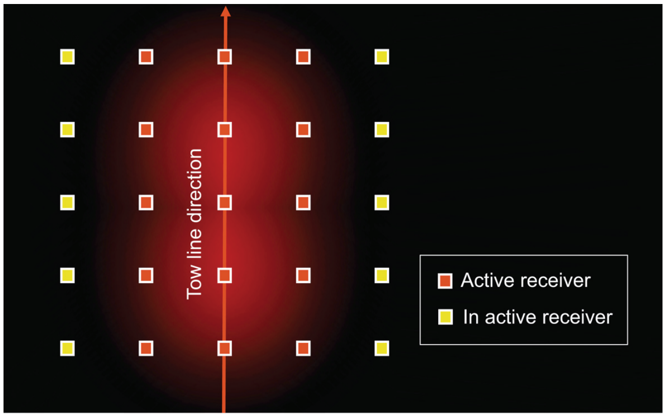

Figure 3: The dipole source beam pattern is adequately captured for receiver spacings of 3–5 km, with one line of active receivers on either side of the line being acquired.

Furthermore, with closer source–line spacing it may be necessary to operate with 5 lines of active receivers, which results in a requirement for over 150 receivers active in the water – a tenfold increase. This requirement is driving the industry towards a second generation of vessel that will have the space and the automation required to efficiently handle these operations on an industrial scale (Figure 4).

Figure 4: Artist's impression of the first custom-built seabed-logging vessel, which is to be launched early in 2008.

It should also be noted that as the scale of operations increases, further technology will be required to automate recovery, deployment, positioning, orientation and performance monitoring for the sources and receivers.

A New Scale of EM Imaging

The increased scale of data acquisition for scanning will also have an impact on data processing. Apart from the obvious increases in human and computer processing power that are required, some of the assumptions of routine EM data processing techniques also require revision.

In particular, it has been customary to identify a single receiver off the prospect and to compare its response with the responses of other receivers. Implicit in this approach is the assumption that variations in background geology and bathymetry are minimal over the survey area. This is a reasonable assumption for most small, target-oriented seabed-logging surveys, but for scanning surveys that span thousands of square kilometres, this assumption is often invalid.

Consequently, a new technique known as reference modelling has been developed. In this process, 1D inversions are performed at several selected locations across the survey area, and a reference model is constructed by interpolating the 1D inversions using an algorithm that honours the available bathymetry data. This technique has been shown to have a dramatic impact on scanning data recorded in areas of significant seafloor relief (Figure 5).

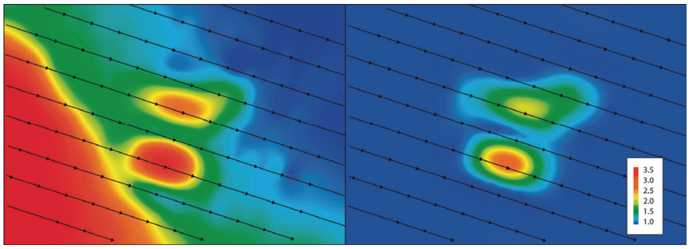

Figure 5: (Left) Modelled data shows bathymetry effects masking the response from two buried reservoirs. (Right) After reference modelling, the reservoirs are seen more clearly.

Summary

Scanning is quickly becoming a key part of the explorationist's armoury of tools, and operators are using it to rapidly generate leads, accelerate prospect delivery, increase discoveries and reduce finding costs in frontier and mature regions (Figure 6). Scanning is performed with current seabed-logging technology, and new enabling technologies are being rapidly developed. Thought processes, workflows, exploration strategies and business models are also evolving to capture the potential value of the technique.

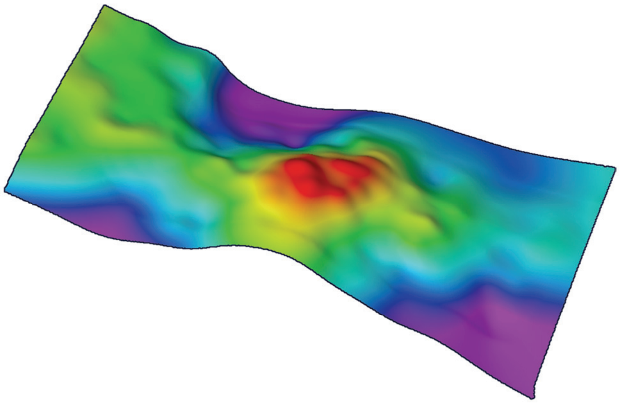

Figure 6: Multiclient scanning data from the Campos basin in Brazil illustrates the power of scanning to reveal buried resistors, including hydrocarbon reservoirs.

Just as 3D seismic surveying reshaped the E&P industry 20 years ago, scanning is driving a new fleet of vessels and a range of innovative business models that will revolutionise offshore exploration.

Acknowledgements

After successful pilot projects in 2005, a team of geoscientists, researchers and operations specialists was assembled to address the challenges of fully commercialising scanning. Less than two years later, the results are impressive. The authors would like to thank F. A. Maaø, M. Panzner and C. Hutchins all of whom have contributed to scanning's success.

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