The Geophysical Corner is a regular column in the EXPLORER, edited by Satinder Chopra, chief geophysicist for Arcis Seismic Solutions, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer. This month's column deals with controlled-source electromagnetic (CSEM) technology impact on exploration investment decisions.

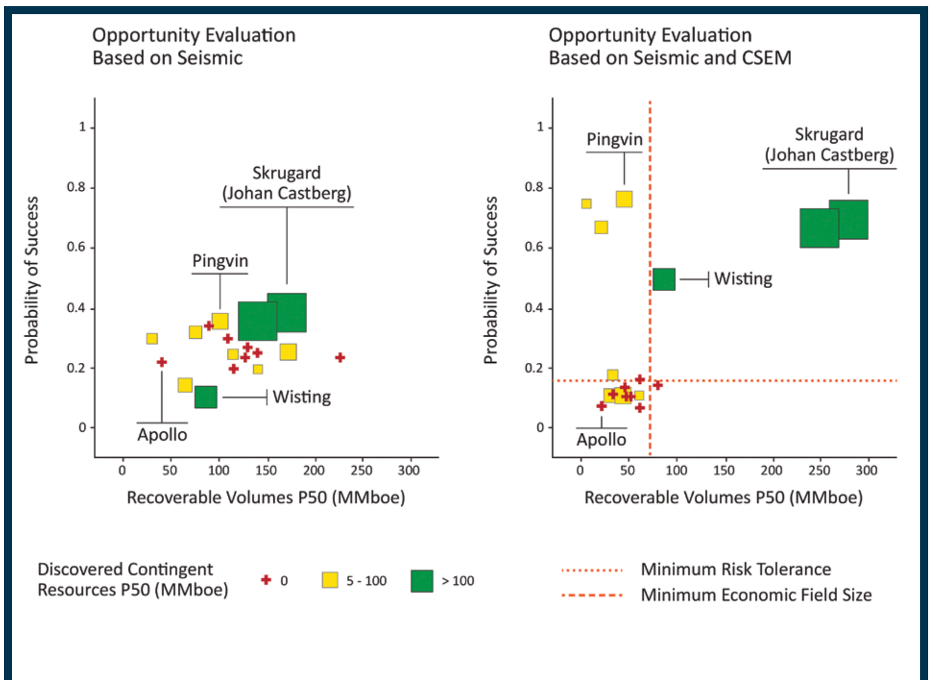

Figure 1 – 18 Barents Sea prospect evaluations compared to well outcomes. Left: Reasonable PoS and P50 volume predictions made from publicly available seismic and geological information. Right: Updated predictions, taking the seismically-focused evaluation as a prior, and updating with 3-D CSEM information.

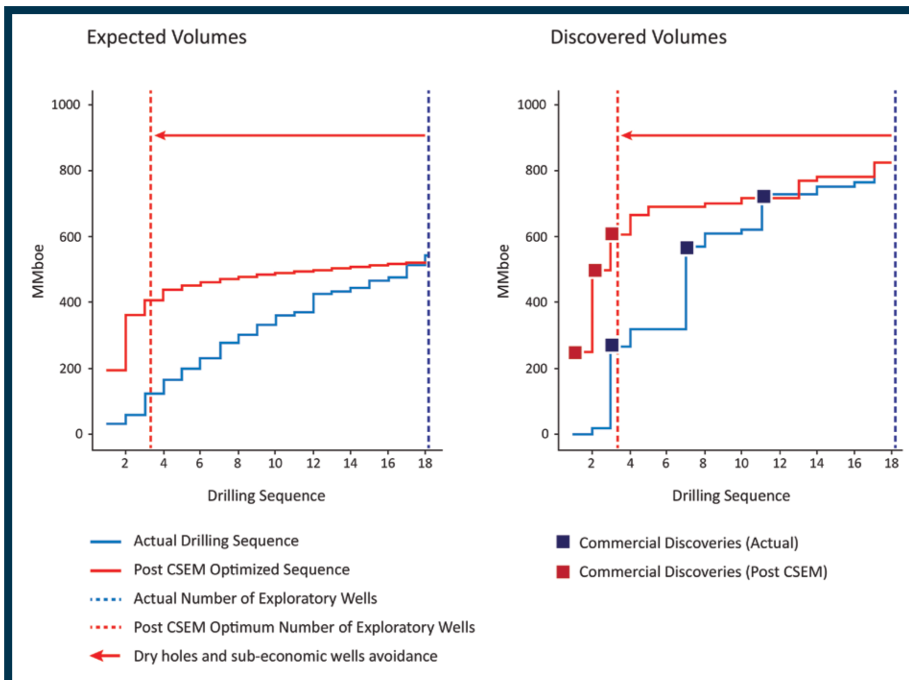

Figure 2 – Impact of CSEM on drilling sequence and number of exploratory wells, optimized based on decreasing expected hydrocarbon volumes (left). Impact of optimized drilling sequence on actual commercial discoveries (right): A three out of three success rate for the post-CSEM sequence; three out of 18 for the actual drilling sequence.

Additional Data Helps Investment Decisions

By DANIEL ZWEIDLER, DANIEL BALTAR and NEVILLE BARKER

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The often-volatile outcome of exploration investment decisions is tightly linked to the level of uncertainty in the geological interpretation and associated value assessment.

In order to evaluate subsurface opportunities, information is needed. This comes at a cost, affecting the profitability of the investment.

Successful exploration companies carefully consider the type of information required to make their decisions, and how the information is to be utilized to minimize uncertainty.

In this environment, the potential impact of new information has to be balanced against both its cost and the ease with which it can be embedded into existing decision-making processes.

CSEM Technology

Seismic methods provide information about the acoustic impedance contrasts between geological layers, allowing for structural definition of geological features and depositional systems analysis. Lateral changes in acoustic impedance and amplitude-versus-offset (AVO) effects provide constraints on lithology and fluid presence.

In contrast, controlled-source electromagnetic (CSEM) technology provides information on subsurface resistivity. In sedimentary basins, resistivity is driven primarily by the quantity of brine in the sediment.

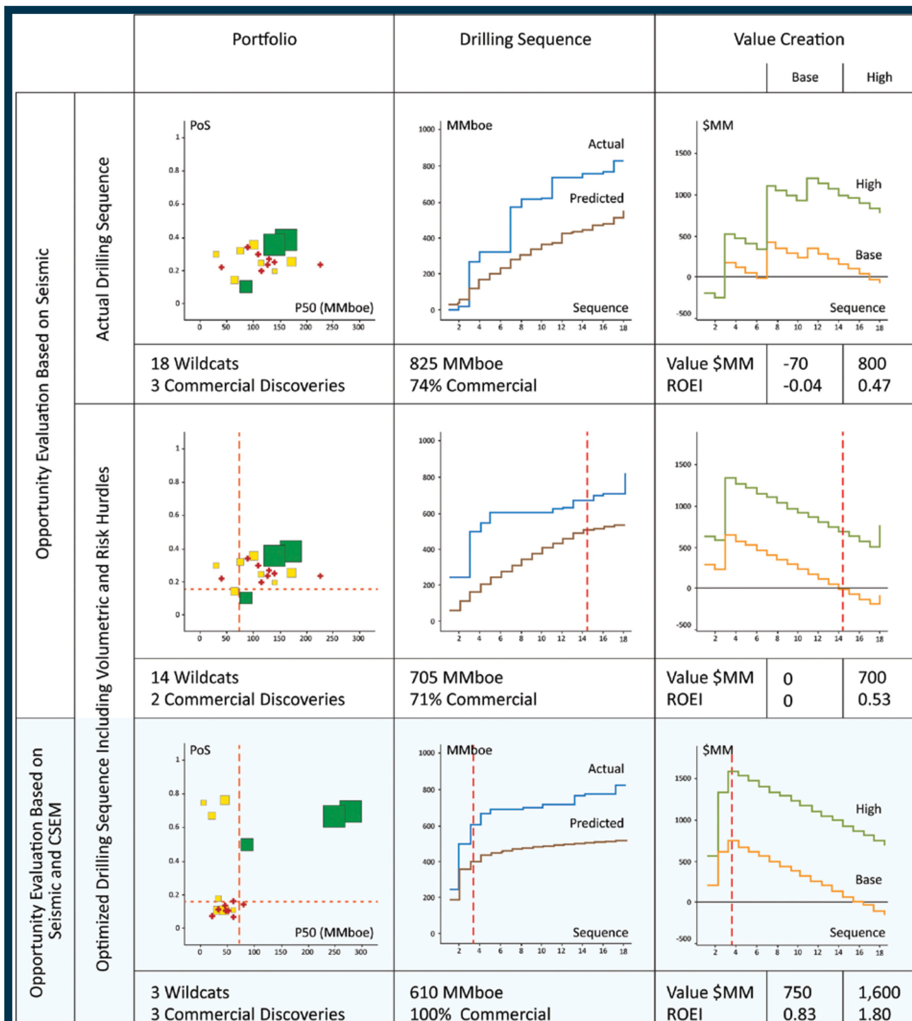

Figure 3 – Summary of the impact of CSEM-enabled investment decisions. The original drilling sequence of 18 exploratory wells delivered three commercial discoveries, with a negative Return on Exploration Investment (ROEI) based on a 60 $/boe world. A drilling sequence based on volumes and risks updated with CSEM information would have delivered three exploratory wells for three commercial discoveries, for an ROEI of 0.83 also based on a 60 $/boe world.

CSEM information also provides constraint on the area and anomalous transverse resistance (net thickness x resistivity contrast) of buried resistive layers.

Hence, the use of CSEM-derived resistivity has the potential to improve our understanding of both fluid distribution and the size of resistive bodies (net rock volume) in a basin.

Conveniently, fluid assessment and net rock volume are two of the largest uncertainties in the conventional opportunity-evaluation workflow; hence, CSEM can potentially reduce some of the largest known uncertainties in exploratory prospectivity evaluation.

Until recently, workflows designed for explorers to handle the CSEM information have been lacking. Instead, technical domain experts have tended to focus on integration approaches designed for lower-uncertainty environments.

This is now changing as Baltar and Barker describe in their 2015 article – "Prospectivity Evaluation with CSEM" – for First Break magazine.

Impact on Investment Decisions

The authors had the good fortune of having access to a best-in-class CSEM dataset in order to analyze its realistic value potential today. The said dataset, from the Norwegian sector of the Barents Sea, covers 18 wells drilled in the period 1988-2015, with half from 2013-14, and only one prior to 2007.

When looking at economic considerations, three of the drilled prospects were arguably successful; all others turned up dry or well below a reasonable economic size.

A quantitative evaluation of the covered prospects based on geological and seismic information leads to a portfolio without obvious clustering (figure 1, left plot).

Baltar and Barker's 2015 article outlined an interpretation workflow designed to integrate the CSEM information into a "seismic technology" portfolio such as this. The approach is based on a Bayesian update to the risk assessment (as widely used in industry for AVO, fluid seeps and other direct hydrocarbon indicators), extended into a coupled risk/volume update in order to account for, and leverage, the additional volumetric sensitivity of the CSEM information.

Resistivity volumes derived from CSEM data-driven processing (rather than a more complex product, integrated at the data level) are used as input in order to maximize transparency of information uncertainties and minimize

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the risk of interpretation bias. When trained explorers applied this workflow, the portfolio of opportunities now exhibits clear polarization and clustering (figure 1, right plot).

What would happen if we could wind back time and optimize the drilling sequence based on this new portfolio evaluation (figure 2)?

Answer: The first three wells to be drilled would be commercial discoveries; any subsequent wells (which should not be drilled based on reasonable risk and volumetric hurdles) would be dry or technical discoveries.

From an exploration efficiency perspective we are looking at drilling three instead of 18 wells with the same overall commercial success.

One could argue that this comparison is unfair, as the original sequence could never be optimized in this fashion due to license timing and well commitments.

In order to address this argument and quantify the potential impact of consistent use of CSEM at a portfolio level, we have calculated the return on exploration investment (ROEI – defined as the net present value divided by the exploration and appraisal investments) for three alternative drilling sequences (actual, optimized without CSEM, and optimized with CSEM) and two oil price scenarios ($60 and $80 per barrel).

Out of the three sequences, only the CSEM portfolio delivers a return above parity in both price scenarios (figure 3).

Conclusions

CSEM technology has grown from its initial research form into a commercial tool with at least one clear value proposition: Known exploration uncertainties can be reduced with the combination of regionally extensive 3-D CSEM information and appropriately trained explorers.

Illustrated here with a dataset from the Barents Sea, the authors have witnessed similar performance in a range of settings globally. We have demonstrated the impact-potential on investment decisions, which has a corresponding effect on exploration capital efficiency.

Harder to quantify is the additional value-potential through reductions in unknown exploration uncertainties, such as hitherto-overlooked play models and missed leads.

The biggest challenge now lies with oil companies, who face the prospect of adapting their exploration workflows and training their people to harness this potential.

Arguably this would be the biggest step-change in the way exploration should be conducted in decades; and like any process change it may be hard to implement, but will undoubtedly be exciting.

Nimbler companies will enjoy the improved capital efficiency. Others may find themselves playing catch-up with this maturing technology. E

(Editor's note: Daniel Zweidler is president of DZA Inc, Ambler, Pa., and Senior Fellow, Mack Institute for Innovation Management, The Wharton School, University of Pennsylvania; Daniel Baltar and Neville Barker are with EMGS in Oslo, Norway. All are AAPG members.)

Geoscience Funding

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– to make the hydraulic fracturing process more efficient and cost effective.

Although geoscience funding was a major topic of discussions, many AAPG members also discussed other hot topics impacting the energy industry during their meetings, including legislation moving through the House and Senate that would lift the ban on oil exports.

AAPG Honorary member Skip Hobbs visited with offices in Connecticut and Massachusetts, which are generally not supportive of the oil and gas industry – but in those meetings he found that many of these offices were open to considering some type of legislation addressing oil exports.

In addition to its participation in GEO-CVD, AAPG also holds a two-day CVD in the spring. Both events offer AAPG members excellent opportunities to cultivate relationships with congressional staff.

Participants also have been able to offer themselves as impartial and reliable resources for congressional staff that are looking for technical information on key issues impacting the oil and gas industry.

In the upcoming AAPG CVD, participants once again will have the opportunity to discuss energy policy issues with their senators, representatives, committee professional staff, the Congressional Research Service and federal agencies, including the U.S. Department of Energy and the U.S. Department of Interior (both the Bureau of Ocean Energy Resources and USGS).

And please note, we welcome non-U.S. AAPG members to attend AAPG-CVD. Energy policy is global, and policy decisions made by one country impact others.

Also, U.S. policymakers are interested in global energy policy developments and their implications for the United States. Last year, for example, we had two AAPG members from Canada participate who were able to arrange a meeting with the Canadian Embassy to discuss issues such as Keystone pipeline and oil sands.

If you would be interested in participating in AAPG's upcoming CVD in March, please feel free to contact either of us on the GEO-DC team: Edie Allison, at Eallison@aapg.org, or Colleen Newman, Cnewman@aapg.org. E