# Modeling Exploration Strategies

## What is the value of systematic use of controlled source electromagnetic information in frontier exploration?

**DANIEL BALTAR** and **NEVILLE BARKER**, EMGS

The value of information (VOI) depends on the targeted decision, how the information is used to affect this decision, and, of course, the information itself. In 2011, at a time when most controlled source electromagnetic (CSEM) surveys were small, 2D and prospect-focused, Buland et al. calculated CSEM VOI for a drill-or-drop decision. In such a case, the maximum value the information can have is the well cost, as the best outcome from an information-value perspective is that the well is not drilled. Today, however, most proprietary and multiclient surveys are 3D, and cover larger areas. The quality of CSEM information has continued to improve, and interpretation workflows have been developed with which it is possible to impact predictions of risk and volume (Baltar and Barker, 2015), and flow capacity (Baltar and Barker, 2017). Here, we calculate a reasonable CSEM VOI for a full exploration project today, and consider the implications for exploration strategy.

### Modeling Frontier Exploration

In a frontier setting, information is particularly limited. Several large structures or stratigraphic features may be identified in seismic, but it is difficult to assess fill-potential, and volumes present, if filled. Prospects therefore typically have a low probability of success (PoS), with high P10 and low P90 volumes (large P10/P90 ratio). Let us consider such an acreage, comprising 20 prospects, where several wells are committed and the acreage will be relinquished if no economic discovery is made. The decision as to which prospects to drill can be made at no cost.

In our synthetic portfolio, each prospect has a PoS drawn from a uniform distribution of between 0.05 and 0.2, and a P10 recoverable volume, drawn from a loguniform distribution of between 300 and 2,500 MMboe (Figure 1a). A constant P10/P90 ratio of 40 is used to derive P90 recoverable volume, and volumes are lognormally distributed. For the
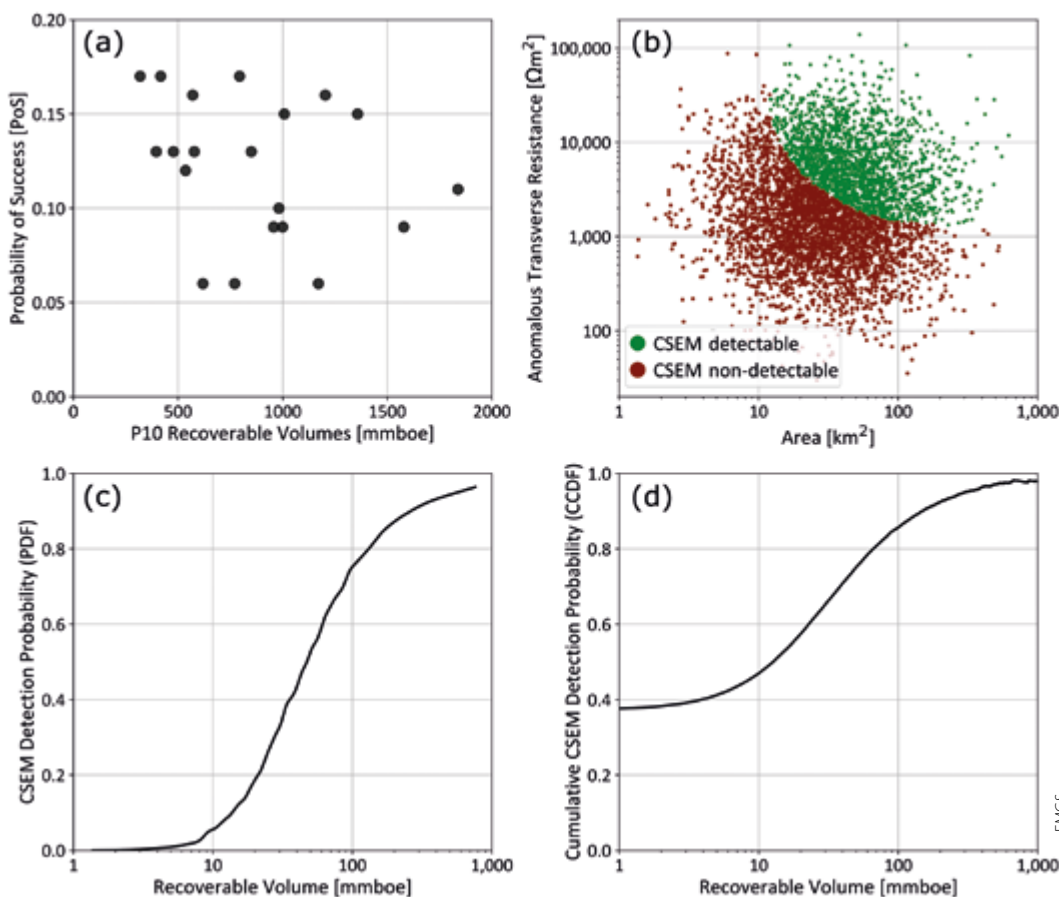


Figure 1: (a) our synthetic exploration portfolio; (b) a Monte Carlo simulation of one representative prospect in the portfolio, buried 3.5 km below mudline, and categorized into those scenarios detectable by a specific CSEM equipment-set, and those that are not; (c) and (d) probability of detection by CSEM for this portfolio as a function of recoverable volume (density and cumulative form respectively). The ability of CSEM to detect a hydrocarbon accumulation is strongly dependent on the filled-reservoir volume, and we can see this dependence for our portfolio in c and d.

sake of simplicity, all prospects are buried at the same depth, 3.5 km below mud line, with 2 km water; their chances of success are independent; and they do not overlap, so only one prospect can be drilled with one well.

Different strategies could be followed when drilling this portfolio, so we will model two alternative decision-makers. In Strategy 1 we will attempt to maximize the PoS and upside-potential by drilling in descending PoS x P10 order, while in Strategy 2, we will acquire CSEM over all the acreage and utilize the same priority list as in Strategy 1, but will postpone the drilling of those prospects where no associated CSEM anomaly has been identified. This is about the simplest reasonable decision-maker that can be conceived for CSEM at the portfolio scale.

We can now use Monte Carlo modeling with 500,000 iterations to simulate our two drilling strategies. Both strategies will use the same data, but in Strategy 2 the filled cases will then be assigned a probability of CSEM detection based on their volume (from Figure 1). To account for false-positive risk, 20% of the dry cases will also be considered CSEM positive, as used by Buland et al., 2011; from our first-hand experience with modern 3D surveys and interpretation workflows, this is very conservative. The final Strategy 2 drilling sequence will then be the Strategy 1 sequence of the EM-positives, followed by the Strategy 1 sequence of the EM-negatives.

Figure 2 shows the mean simulation outcome, where economic success is calculated with respect to a minimum economic field size of 300 MMbo. With Strategy 1, in the absence of CSEM, the cumulative probability of economic success (Pe) increases almost uniformly with the number of wells (Figure 2d). The introduction of CSEM leads to a more rapid increase in cumulative Pe for the first wells, with a reduction in the rate of increase after only a few wells. In other words, the acreage is being more efficiently creamed.

## Value of CSEM Information

The value of the CSEM information is the expected difference in the project's value with and without the CSEM. Project value can be calculated with the following formula:

$$V_{exp} = NPVe\ Pe - (1 - Pe)\ C_{exp}$$

where $V_{exp}$ is the value of the exploration venture, $NPVe$ is the average Net Present Value of an economic success, and $C_{exp}$ is the cost of the exploration project. We weight the cost of exploration by $1-Pe$ because we consider this cost to be discounted from the $NPVe$.

The CSEM value stems from the increased chance of making an economic discovery in one of the committed wells. The increase in $V_{exp}$ can be written as the difference between the expected value of each of the branches of the corresponding decision tree:

$$\Delta V_{exp} = \Delta\ [NPVe\ Pe] - \Delta\ [(1 - Pe)\ C_{exp}]$$

For a technology to be valuable, $\Delta V_{exp}$ must be greater than zero, and hence $\Delta[NPVe\ Pe]$ must be greater than $\Delta\ [(1 - Pe)\ C_{exp}]$.

Let's now take our exploration acreage and include a commitment to 3D seismic acquisition and the drilling of

two exploratory wells at a total cost ($C_{exp}$) of US$500 million. This leads to a Strategy 1 *Pe* in the range of 3 to 6%. In contrast, with the addition of CSEM, the Strategy 2 *Pe* is 17% (Figure 2c). The cost of a CSEM survey depends on the water depth, area to be covered, and receiver spacing (which can be relatively sparse in a frontier setting). A reasonable upper limit for the type of project needed here would be US$40 million. Using this budgetary figure we can now compare *Δ[NPVe Pe]* with the cost of CSEM (Figure 3a). For any reasonable project (with original $V_{exp} > 0$), the *Δ[NPVe Pe]* significantly outweighs (by more than 20 times) the upper limit of the CSEM cost. This means that the value of a typical exploration venture can
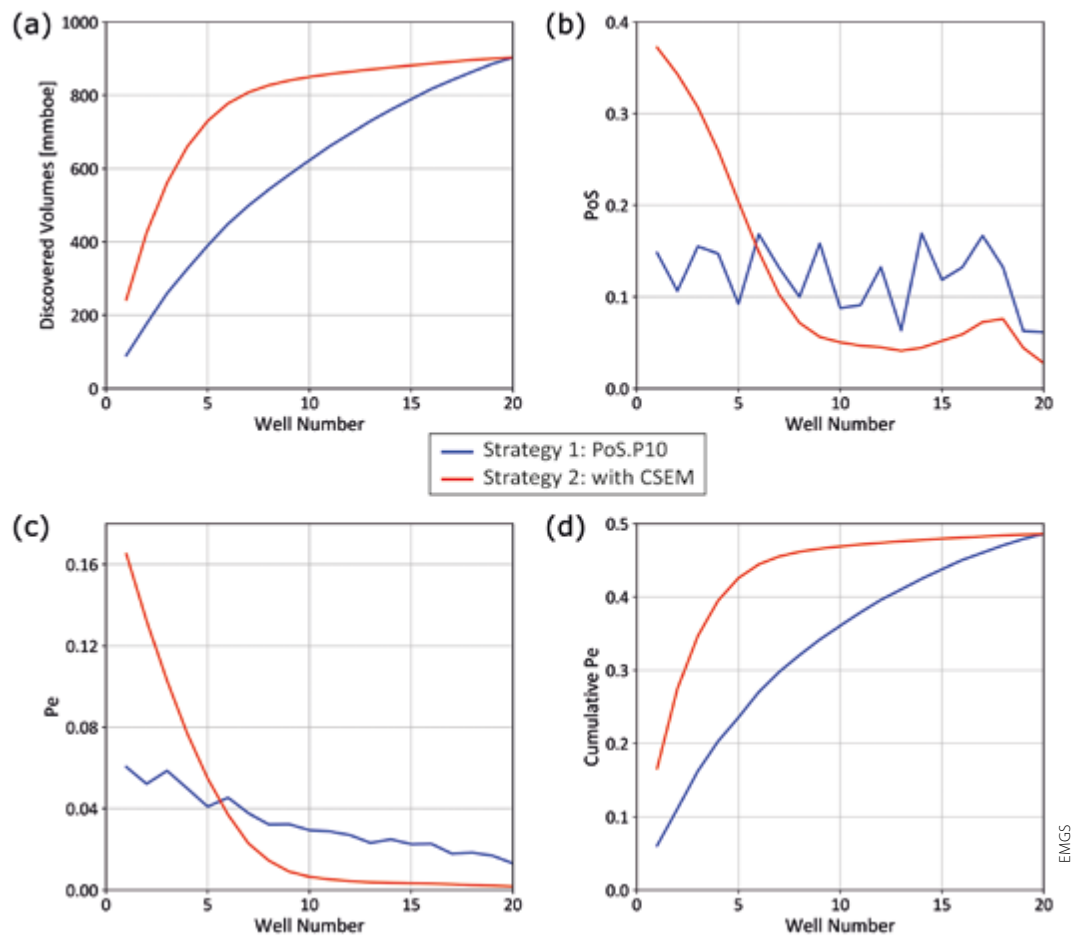


*Figure 2: Mean outcomes for the two exploration strategies as a function of number of wells drilled, illustrating the performance improvement that can be expected with the addition of CSEM information.*

be greatly increased by systematic use of CSEM to improve the drilling sequence.

Interestingly, as well as improving the portfolio creaming, the addition of CSEM also leads to a change in the project's economic threshold: with the increase in *Pe*, there is a corresponding change in the position of the $V_{exp} = 0$ line (Figure 3b), one of the potential exploration-venture threshold criteria. Therefore the additional value gained from CSEM is large enough that projects with significantly smaller *NPVe* may now be considered.

The use of CSEM information for drilling sequence improvement, as detailed here, is a very simple application of the technology; however, we have shown that the resulting VOI can be extremely high, even when assuming an unrealistically high technology cost and high false-positive risk. The inclusion of embedded workflows for the re-evaluation of risk, volumes and reservoir quality only serves to further increase this potential value. Acquisition of CSEM even earlier in the exploration lifecycle can also lead to the potential for influencing commitment and bidding decisions. Combine the above values, and we see a bright future for CSEM data acquisition far earlier in the exploration process than was expected from its drill-or-drop origins.
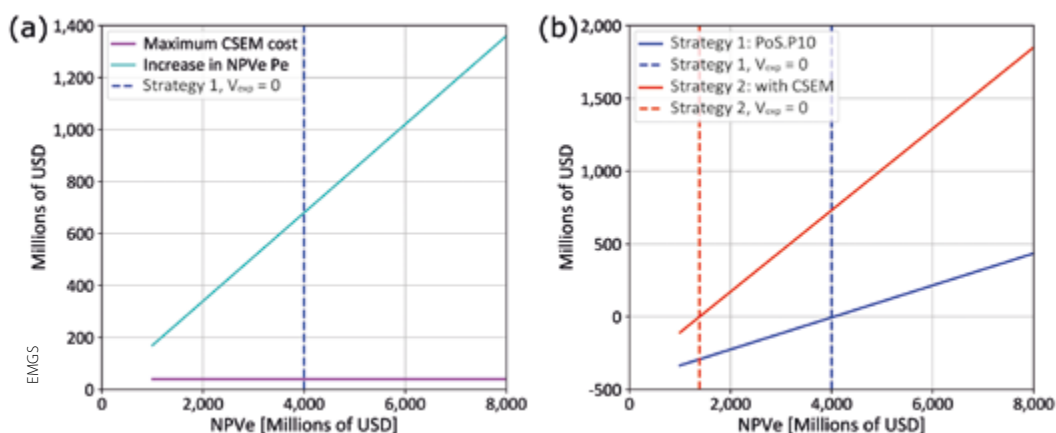*References available online.* ∎



*Figure: 3 (a) value of CSEM information as a function of the venture NPVe, versus its cost, showing that, if applicable, the consistent use of CSEM for drilling sequence improvement outweighs its cost many times; (b) the consistent application of CSEM impacts the expected value of the exploration project, making it possible to improve the value of otherwise sub-economic exploration ventures.*