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Value of Seismic Information with Multiple Drilling Targets

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SUMMARY

Previous work has focused on valuing seismic information in the context of a go/no-go decision surrounding a single hydrocarbon target. While useful, this scenario fails to address the more common decision situation facing most oil and gas companies: the development of a multi-target drilling program in the face of constrained resources (e.g., capital, rigs, time). In this paper, we quantify the value of seismic information when facing some form of drilling or budget constraint. In so doing, we demonstrate that seismic information is potentially more valuable than has been shown before. We also highlight the importance of quantifying seismic accuracy in different geologic settings.

Introduction

Seismic information, both static and time-lapse, offers the possibility to improve oil and gas drilling and development decisions. While the cost of a seismic survey is readily quantifiable, its value is generally not. How can we value a survey before its results are known? How can we value different acquisitions methods or differences in seismic survey accuracy before commissioning the survey?

The concept of *value of information* can address these questions. Seismic information has value only to the extent that it offers the possibility of changing drilling or development decisions. For example, simply changing probabilities of success will not create value if the well would be drilled no matter the result of the seismic survey.

Previous work has focused on the value of seismic information (static or time-lapse) in the context of a single reservoir target (Stibolt and Lehman 1993; Waggoner 2002; Ballin et al. 2005). While useful, this scenario fails to address the more common decision situation facing most oil and gas companies: development of a multi-target drilling program in the face of constrained resources (e.g., capital, rigs, time). In this work, we develop a methodology to value seismic information in terms of its impact on a multi-well drilling program. By so doing, we demonstrate that when facing a drilling constraint (e.g., total capital budget), significant value can be created by a seismic survey through its ability to prioritize drilling targets. This is true even if the seismic survey does not change the drilling decisions on any single target, in the absence of a drilling constraint. This result suggests that previous work, which focuses on a single target, significantly underestimates the value of seismic information.

Method

Let $\boldsymbol{d} = (d_1,\ldots,d_n)$ be an n-vector of drilling decisions, or a drilling program, where $d_i = 1$ if target i is to be drilled and 0 otherwise, and n is the number of possible targets. The prior probability of success is $\boldsymbol{p} = (p_1,\ldots,p_n)$, where p_i is the probability of finding hydrocarbons at target i without the benefit of additional seismic information. We will assume the targets are probabilistically independent. The expected monetary value (*EMV*) of $\boldsymbol{d}$ is $EMV(\boldsymbol{p},\boldsymbol{d}) = \sum_i \max[p_i v(d_i)-c_i,0]$, where $v(d_i)$ is the expected net present value of well i given success, not including drilling costs, and c_i is the cost to drill well i. The maximization represents the fact that we do not have to drill any targets with a negative value. In addition, we assume there is a constraint on the drilling program (e.g., a capital expense constraint or targeted well budget) such that it may not be possible to drill every positive *EMV* target.

Let $\boldsymbol{d'} = (d'_1,\ldots,d'_n)$ represent the drilling program given seismic information $\boldsymbol{\theta} = (\theta_1,\ldots,\theta_n)$. θ_i is the processed seismic signal for target i. As a simple example, consider θ_i to take on only discrete values of "Successful" (S) or "Unsuccessful" (U). The posterior probability of success $\boldsymbol{p'}(\boldsymbol{p},\boldsymbol{\theta}) = (p'_1,\ldots,p'_n)$ is obtained using Bayes' Rule and depends critically on the accuracy of the seismic signal. The *EMV* of the drilling program $\boldsymbol{d'}$, with seismic information, is $EMV(\boldsymbol{p'},\boldsymbol{d'}) = \sum_i \max[p'_i v(d'_i)-c_i,0]$, where we again assume this optimization is performed under some form of budget constraint.

The value of a seismic survey (*VoS*) is the *EMV* of the optimal drilling program with seismic information less the *EMV* of the optimal drilling program without seismic information; $VoS = EMV(\boldsymbol{p'},\boldsymbol{d'}) - EMV(\boldsymbol{p},\boldsymbol{d})$.[1]

[1] This commonly used definition of the value of information is correct only for companies with constant risk aversion (e.g., risk neutral).

Illustrative example

The method developed above can be applied to decisions regarding the acquisition and design of both static and time-lapse seismic surveys. In the interest of brevity, in this section, we consider an extension of a 4D example presented in Waggoner (2002). Waggoner considered the drilling of a single well after obtaining 4D seismic information about a single target.[2] In this example, we will assume 12 targets, each identical to Waggoner's single target. Each target has a prior probability of success of 0.75. The economic value of a successful well is $50 MM and each well costs $5 MM to drill. The breakeven probability of success for each well is 0.10 ($5/$50). Since the prior probability of 0.75 is greater then the breakeven of 0.10, all 12 targets would be drilled in the absence of a drilling constraint.

Assume that a seismic survey can be performed and will return only two possible readings: successful (S) or unsuccessful (U), and has an accuracy of 0.75. This accuracy means that the survey will report "S" with probability 0.75 for an ultimately successful target; likewise, for an ultimately unsuccessful target, the survey will report "U" with probability 0.75.

According to Bayes' Rule, the probability of a successful target given the survey reports "S" is p(S|"S") = 0.90 and the probability of S if the survey reports "U" is p(S|"U") = 0.50.[3] As both these probabilities are greater than 0.10, and in the absence of a drilling constraint, all 12 targets will be drilled *no matter what the seismic survey reports*. Does this imply the value of the seismic survey is zero? Not if there if a drilling constraint. Figure 1 displays the VoS as function of the number of wells that can be drilled. In addition to an accuracy of 0.75, Figure 1 also displays an accuracy of 0.70 for comparison. As discussed above, the VoS is $0 if all 12 wells could be drilled. However, if only 7 wells can be drilled the VoS equals almost $45 million. Decreasing the accuracy to 0.70 reduces the VoS for a 7-well budget to $35 million. Figure 1 also displays the difference in VoS(0.75) and VoS(0.70). Figure 2 displays the sensitivity of VoS with an accuracy of 0.75 to the number of targets and the well budget. On average, every 0.01 increase in accuracy is roughly worth about $1 million. Quantifying seismic accuracy in different geologic settings and using different acquisition/processing technologies is critically important, as even small accuracy increases can create significant value.

Clearly, the accuracy of the processed seismic signal is a critical determinant of value. Figure 3 displays the VoS for 12 targets with a 7-well budget as a function of accuracy. At an accuracy of 0.50, the VoS = $0. At an accuracy of 1.0, the VoS = $84 million, which is the value of perfect information.

Conclusion

Seismic surveys (static and time-lapse) offer the promise of improving drilling and development decisions. Before performing a survey, it is important to quantify its benefit and value. Previous studies, by focusing on a single drilling decision, have tended to under-value seismic information. By focusing on the multiple targets and an optimal drilling program, we can better quantify the value of seismic information.

References

Ballin, P., Ward, G., Whorlow, C. and Kahn, T. [2005] Value of Information for a 4-D Seismic Acquisition Project. SPE Latin American and Caribbean Petroleum Engineering Conference, SPE 94918.

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[2] Waggoner implicitly assumed an infinite number of drilling targets. As a practical matter, the value that is obtained by assuming an "infinite" number of targets is obtained for approximately four or more targets.

[3] p(S|"S") = 0.75(0.75)/(0.75(0.75) + 0.25(0.25)) = 0.90. p(S|"U") = 0.75(0.25)/(0.75(0.25) + 0.25(0.75)) = 0.50.

Stibolt, B. and Lehman, J. [1993] The Value of a Seismic Option. SPE Hydrocarbon Economics and Evaluation Symposium, SPE 25821.

Waggoner, J. [2002] Quantifying the Economic Value of 4D Seismic Projects. SPE Reservoir Evaluation and Engineering, April, 111-115.

Figures

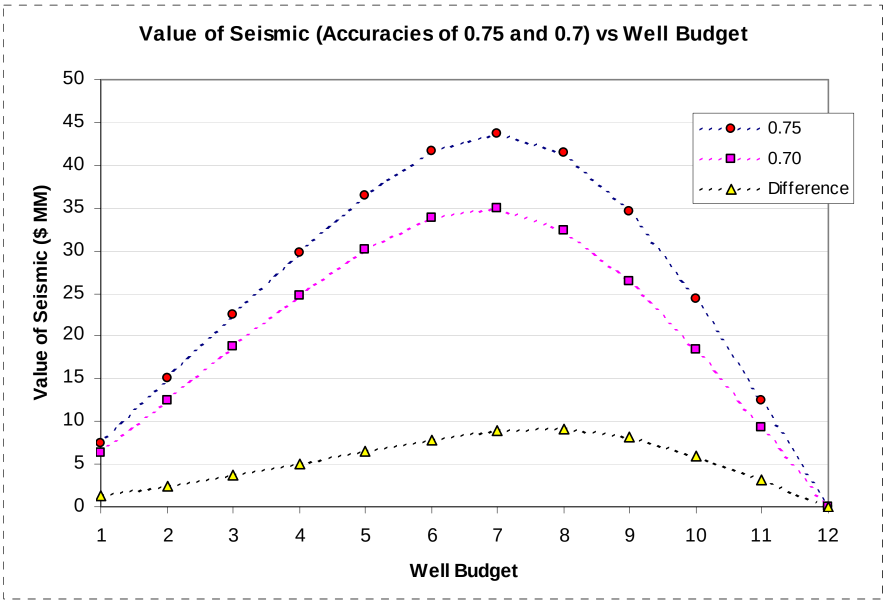

Figure 1. Value of seismic information with budget constraint

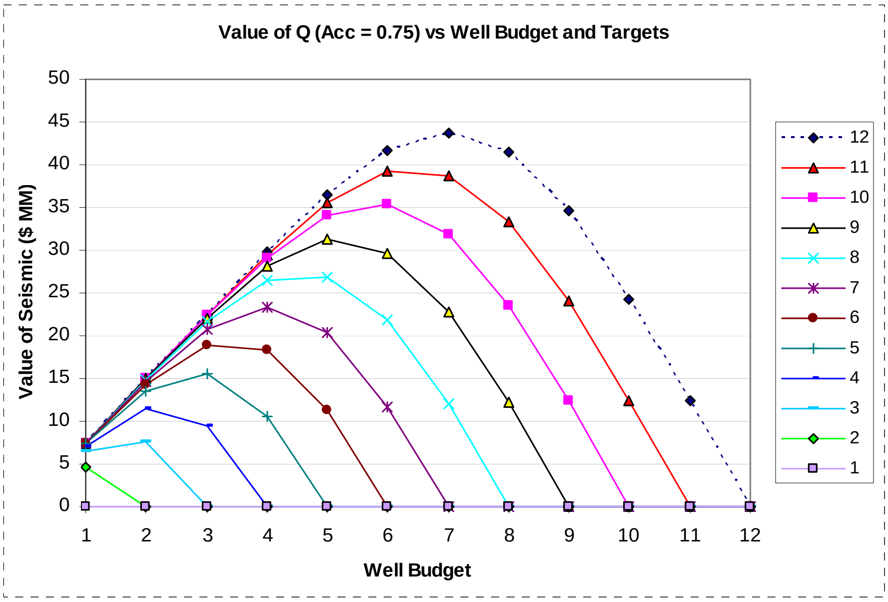

Figure 2. Value of seismic information sensitivity to budget and targets

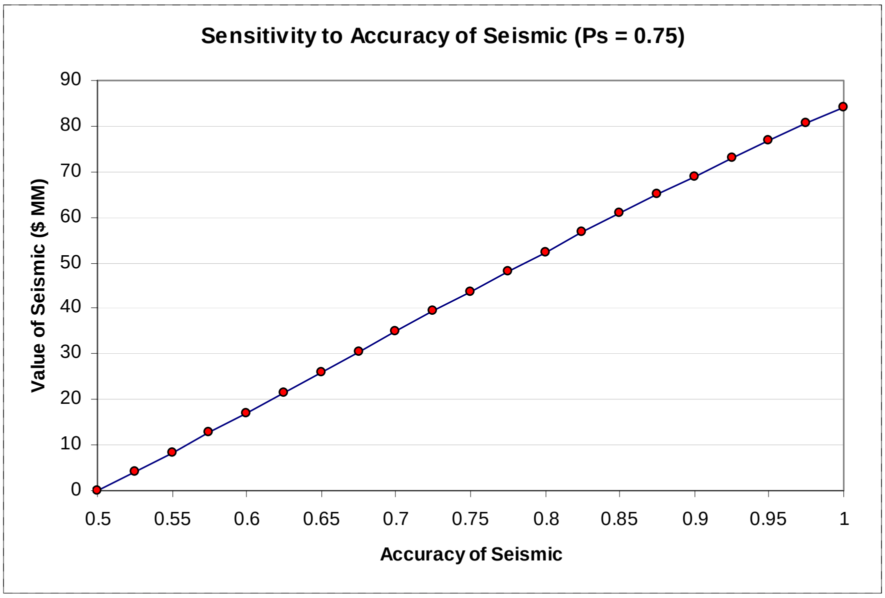

Figure 3. Value of seismic information versus accuracy for 7-well drilling budget