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< Previous Paper

Table of Contents

Next Paper >

Citation | PDF | PDF w/Links (79 KB)

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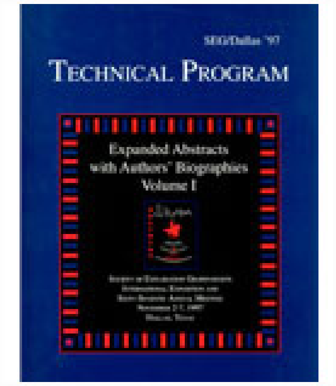

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Assessing the Technical Risk of a 4D Seismic Project

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SUMMARY

We have developed a *"4D seismic technical risk spreadsheet"* as a quantitative tool to help decide whether it is technically advisable to perform a time-lapse 4D seismic monitoring project for a specific reservoir and field site (Lumley et al., 1997). The spreadsheet lists the reservoir and seismic parameters that are vital to the technical success of any 4D project, and ranks each with a score range of 0 to 5. In order for a 4D project to be considered likely to succeed, the reservoir and seismic parameters must obtain a passing score of at least 60% for each of the reservoir and seismic subtotals. Field example values are given for Chevron 4D seismic projects in Indonesia, the Gulf of Mexico, West Africa and the North Sea.

INTRODUCTION

Over the past few years, Chevron has embarked on many 4D seismic projects world-wide. To facilitate this activity, Chevron Petroleum Technology has a team of technical experts dedicated to researching, developing and optimizing the 4D seismic technique. At the initial stages of any 4D project, the following question is usually asked of us by our business-unit engineers and geoscientists: "we have a field which we are thinking about for 4D seismic reservoir monitoring, do you think it will work?'. The answer to that question can be a complex mix of scattered responses from a diverse range of technical experts in reservoir engineering, petrophysics and seismology. A collection of such responses may appear to be a somewhat unsatisfyingly qualitative "yes, it should be great", or "could be risky", or "no, that will never fly". Or even worse: "give us $100k to do a complete feasibility study and well get back to you in a few months."

We decided we needed an analysis tool that answered this question in a quick (one day) and quantitative (numerical score) manner, using a simple subset of the most important reservoir and seismic variables that have a first-order affect on a 4D seismic project. The result is our 4D technical risk spreadsheet. The following sections describe how to fill in the 4D risk spreadsheet and how to interpret the results. We believe this framework for 4D seismic risk analysis is unique in the industry and will be very useful to anyone planning their own 4D seismic project.

STEP 1: COMPLETING THE 4D FACT SHEET

The first step is to fill in a 4D Fact Sheet (not shown here due to space limitations). It consists of sections for values of "Reservoir", "Rocks", "Oil", "Water", "Gas", "4D Fluids", and "Seismic". The entries represent the raw information at a reservoir and field site that is needed to determine the probability of success for a 4D seismic project. The following descriptions help clarify some of the entry data needed for the 4D Fact Sheet.

depth:
In general, shallow depths are more favorable for 4D seismic imaging of fluid flow effects. This is because seismic frequency content tends to be high, allowing high resolution images, and rocks tend to be unconsolidated and compressible, and sensitive to the fluid content. The Indonesia values are a good example of this effect.

net pressure:
Net pressure is defined as the difference between overburden pressure and pore pressure. Generally, reservoir rocks are more likely to show the effects of fluid saturation and pressure change when the net pressure is low. This occurs when the pore approaches the overburden pressure, as often occurs with the injection of gas, steam, water or C02, for example. The North Sea example (water injection followed by depletion) and the Indonesia example (steam injection) demonstrate this effect. We are finding that the effects of pressure during reservoir production are more seismically visible than previously thought (Lumley, 1995; Lumley et al., 1995).

bubble point:
Bubble point is the pressure, at a fixed temperature, at which dissolved gas first starts bubbling out of solution. Reservoirs that cross the bubble point in either direction, either by pressure depletion or fluid injection, can be useful in 4D seismic applications for mapping pressure compartmentalization, fault sealing properties, and hydrocarbon saturation fronts. The Indonesia example shows that the reservoir started at 10 psi below bubble point before steam injection, and then increased to as much as 240 psi above bubble point after steam injection. The initial gas in pore space dissolved after pressure injection, and this effect was easily mappable in the 4D seismic sections (Bee et al., 1994; Lumley et al., 1995).

temperature:
Generally, reservoir oils at a high temperature are more compressible than water and so offer a better chance of being monitored seismically. In the Indonesia example, the oil is initially so incompressible as to be considered a part of the rock matrix, but after heating, became more even compressible than water.

unit thickness:
Unit thickness is the thickness of the reservoir zone(s) to be monitored. Generally this thickness should be greater than half a seismic wavelength in order for fluid-flow changes to be vertically resolved. A seismic wavelength is defined as the average reservoir rock velocity divided by the dominant seismic frequency value.

dry bulk modulus:
The dry bulk modulus refers to core measurements made at non-saturated or gas-filled conditions. Rocks with a low dry bulk modulus are very compressible, and hence their compressibility at saturated conditions will be a strong function of the fluid type in pore space. This situation is typified by the unconsolidated rocks in the Indonesia and Gulf of Mexico examples. In contrast, rocks with a large dry bulk modulus are very incompressible, and their compressibility changes very little as a function of saturation conditions. This would be the case for the very deep consolidated rocks with high carbonate content in the North Sea example.

porosity:
Seismic waves average over large volumes of reservoir rock. Therefore, for subtle fluid changes to be detected seismically, a large volume of rock needs to undergo fluid replacement. This suggests that high porosity rocks are more favorable for 4D seismic.

GOR:
GOR is the solution gas-to-oil ratio. Oils with large GOR values tend to be very compressible and light, thus providing a good contrast in seismic properties to brine water. The Gulf of Mexico, West Africa and North Sea examples all show this effect.

salinity:
Seawater has a salinity of about 40,000 ppm. Reservoir water that is extremely salty, say near 200,000 ppm, can be considerably less compressible than seawater or typical oil. This extra “stiffness” of saline water can help seismically distinguish it from oil, as shown by the Gulf of Mexico and North Sea values.

4D fluid saturation change:
4D fluid saturation change is the difference in initial and final saturation values of the fluid to be monitored. For the West Africa example, an oil/water system is to be monitored. The initial oil saturation is 75% and the final swept saturation is 25%, resulting in a 50% change in fluid saturation conditions. In the Indonesia example, steam is the fluid component to be monitored. The initial fluid saturation is 90% and the final fluid saturation after steamflooding is 10%, resulting in an almost ideal 80% fluid saturation change.

4D fluid compressibility contrast:
This is the change in bulk modulus from fluid1 to fluid2: (Kf2 - Kf1)/(Kf1), where fluid1 is the initial fluid in pore space (say, oil), and fluid2 is the replacement fluid (say, water). Generally, the larger the fluid compressibility contrast the better chance of being able to seismically image the two fluids separately. The Indonesia example shows that the compressibility contrast between steam and oil/water is more than 1 ,OOO%! More typical values of 125% are shown for the West Africa example of injected seawater displacing live oil.

dominant seismic frequency:
The higher the dominant frequency of seismic energy, the better the ability to resolve changes in the reservoir unit. The Indonesia example shows an exceptionally ideal case of 125 Hz dominant (250 Hz maximum) frequency content, obtained by buried dynamite shots and receivers for a very shallow reservoir target. The Gulf of Mexico, West Africa and North Sea examples show more typical values for conventional seismic recording.

average resolution:
The average resolution in a seismic image is defined as a quarter of a seismic wavelength. A seismic wavelength is defined as the average reservoir rock velocity divided by the dominant seismic frequency value. Optimal seismic resolution requires low velocity (unconsolidated) rocks and very high frequency seismic energy.

image quality:
Image quality refers to general signal-to-noise (s/n) quality, the ability to image reservoir reflections, and overall image clarity. For most 4D seismic applications, the reservoir should be well imaged, and amplitude variations along the reservoir reflection should be accurate and meaningful. All of the examples have this quality, except the North Sea example in which the reservoir reflection in any given survey is weakly visible at or near the noise level.

repeatability:
Optimal 4D seismic imaging requires seismic acquisition and processing to be “repeatable” from survey to survey, so that differences between two time-lapse seismic images can be trusted as real changes due to reservoir production, not acquisition or processing artifacts. Enhanced acquisition repeatability includes using the same acquisition method for each survey (say, marine streamer both times), accurate source and receiver positioning (perhaps even using a permanent installation), shooting seismic lines in the same direction for each survey, and using the same bin spacing and offset/azimuth distribution. The Indonesia example has all of these qualities. The North Sea example was shot in different directions with some question of positioning accuracy. In many cases, we have fields that were originally shot as streamer surveys before production, but now have so many added platforms and facilities that all future surveys will have to be ocean bottom cable, hence losing some potential acquisition repeatability.

fluid contact visibility:
This refers to the ability to clearly see fluid contacts in seismic over wide areas. This can be an important factor for 4D seismic, since monitoring fluid movement may simply reduce to mapping the new fluid contacts in each successive seismic survey. All the examples in Table 1 exhibit good seismic fluid contact visibility, except the North Sea example due to the deep consolidated rock properties.

traveltime change:
Traveltime change is predicted for a reservoir rock by changing all anticipated saturation, pressure and temperature conditions from monitor time 1 to time 2, including all reservoir production effects. Most reservoirs show almost no traveltime change during reservoir production. Instead, fluid changes show up as amplitude changes along stationary reflection events. An exception to this is the Indonesia steamflood example, and to a lesser extent the West Africa example in which gascaps have been produced ("blown down") from various reservoirs in between seismic surveys. A good rule of thumb for seismic detection is that traveltime changes between surveys should be greater than four time samples.

impedance change:
Impedance change is predicted for a reservoir rock by changing all anticipated saturation, pressure and temperature conditions from monitor time 1 to time 2, including all reservoir production effects. Seismic reflection amplitude is proportional to half the impedance change. Most reservoirs with unconsolidated rocks, brine and high-GOR oil, and depths less than 10,000 ft. show amplitude changes due to fluid or pressure change during production. A good rule of thumb for seismic detection is that impedance changes between surveys should be greater than 4%. Unconsolidated sands and live oil in the Gulf of Mexico generally exceed this value. West Africa rocks and fluids tend to give slightly smaller amplitude changes. Deep, consolidated, high-carbonate content rocks in the North Sea can show significantly smaller impedance changes.

REMAINING STEPS

Once the Fact Sheet has been completed, we gather a concise set of reservoir and seismic variables, and assign them each scores on a O-5 scale to give a quantitative risk assessment. At the presentation, we will show explicitly how we assign scores to each variable (space does not allow this here). These "scores" are based on our experience evaluating numerous 4D seismic projects in a variety of production scenarios, and reservoir and field conditions. Once the critical reservoir and seismic variables have been scored, they can be entered into the 4D Technical Risk Spreadsheet. An example is shown in Table 1. This spreadsheet compresses the 4D seismic technical risk assessment to five reservoir variables and four seismic variables.

Using the 4D Technical Risk Spreadsheet, we can assess the risk of doing a 4D project at a given field. There are three major components of this analysis: reservoir conditions, time-lapse seismic conditions, and combined total score. We will discuss how to use the spreadsheet results at the presentation.

CONCLUSION

We present a method for assessing the technical risk of a 4D seismic reservoir monitoring project in any production, reservoir and field conditions. The 4D technical risk spreadsheet is quick in that it can be filled out in one day or so, is first-order accurate in that is uses the most critical subset of 4D seismic parameters, and quantitative in that numerical scores are assigned to each parameter based on our experience with numerous 4D seismic projects. It is very useful for designing a given 4D project, and comparing its risk with other 4D projects world-wide that have been similarly quantified and archived. If the risk assessment shows that a given reservoir may be a good candidate for a 4D project, the spreadsheet can highlight areas for further follow-up work in a more complete feasibility study.

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REFERENCES

Bee, M. F., Jenkins, S. D., Lyle, J. H., and Murhanto, E., 1994, A powerful new technology for monitoring steam movements in Duri Field, Central Sumatra: 23rd Annual Conv., Proceedings, Indonesian Petrol. Assoc.

Lumley, D. E., Behrens, R. A., Wang, Z., 1997a, Assessing the technical risk of a 4D seismic project: The Leading Edge, in review.

Lumley, D. E., 1995, Seismic time-lapse monitoring of subsurface fluid flow: Ph.D. Thesis, Stanford University.

Lumley, D. E., Bee, M., Jenkins, S., and Wang, Z., 1995, 4-D seismic monitoring of an active steamflood: 65th Annual Intemat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 95, 203-206.

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