Quantitative Interpretation of Time-Lapse Seismic for a SAGD Reservoir at Jackfish, Alberta

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Summary

Quantitative interpretation based on time-lapse joint PP-PS inversion and rock physics models were used to estimate three stages of the production cycle of an oil-sands reservoir at Jackfish. The goal was to use seismically-derived elastic properties for imaging steam chamber extension, changes in fluid saturation within the reservoir, the extension of the warmed bitumen (future production zones), and temperature distribution inside the reservoir. Probability density functions (PDFs) are derived from elastic properties of a time-lapse observation log and compared to the seismically-derived properties from the 4D seismic inversion.

Introduction

Observations and measurements derived from time-lapse inversion analysis are important in understanding how the temperature, pressure and fluid saturation change in time. Time-lapse joint PP-PS inversion analysis provides one set of elastic properties (P- and S-wave velocities and density) for the baseline and one set for the monitor. The differences between the monitor and base elastic properties represent the time-lapse changes. These differences, when imaged in 3D space, provide the basis for interpreting changes in the reservoir to due production.

Method

For quantitative interpretation we integrated time-lapse inversion results with a rock physics model. Our rock physics model links elastic properties with temperature, pressure and fluid saturation. Lab results (Kato et al., 2008) and data acquired in a time-lapse well allowed us to characterize three stages within the production reservoir: “in situ”, “mobilized oil” and “displaced oil”. For each of the three stages, probability density functions (PDFs) were defined in crossplots of time-lapse elastic properties logs and temperature curves.

The time-lapse elastic properties and temperature seismic volumes were also analysed in crossplot space and calibrated with the knowledge from the time-lapse logs. The clusters derived from these crossplots were projected in the 3D volume. The result is a cube showing probabilities (0-100%) for each of the three stages. Higher probabilities were used to create equivalent geobodies around the horizontal-producing wells.

Conclusions

Time-lapse P-impedance difference is a very good indicator for the presence of heat. Time-lapse VpVs ratio is a good indicator of “mobilized oil” zones where bitumen has lowered its viscosity and now flows. It also can be used to characterize “displaced oil”, where the steam has replaced the produced oil. PDFs defined in cross-plots from time-lapse elastic properties are used to estimate the uncertainty of three stages of production: “In situ”, “mobilized oil”, and “displaced oil” in the reservoir.

References

Kato, A., S. Onozuka, and T. Nakayama, 2008, Elastic property changes in a bitumen reservoir during steam injection: The Leading Edge, 27, 1124-1131