Submission code: JA967PR8B7

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Direct probabilistic AVO inversion in VTI media

Raul Cova (Qeye), Evan Mutual (Qeye), Bill Goodway (Qeye), Scott Leaney (Qeye), Henrik Hansen (Qeye), Ask Jakobsen (Qeye), Wendell Pardasie (Qeye)

SBGf Conference 18-20 NOV | Rio'25

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Introduction

Probabilistic inversions allow for improved vertical details and a more comprehensive statistical analysis of the possible solutions to the AVO inverse problem. Here, we apply the anisotropic direct probabilistic inversion (DPI) introduced by Cova et al (2021). We first illustrate this method using an anisotropic model built for an unconventional reservoir where facies classification can be challenging due to the low contrast in elastic properties among all facies. We also show the results of the application of this method on field data from a conventional reservoir offshore in the East Coast of Canada.

Method

DPI is a single-step inversion process which inverts pre-stack seismic data directly for geologic facies. It is based on the Bayesian probabilistic framework developed by Jullum and Kolbjørnsen (2016). In the case of VTI-DPI, Ruger's AVO approximation is used as the forward modeling operator to compute the likelihood function. The benefits of this approach are two-fold. First, the model space is expanded from three (AI, Vp/Vs, density) to five elastic parameters which now includes the two weak anisotropy Thomsen parameters ε and δ. This provides an opportunity for resolving elastic ambiguities that might not be resolved by using only three isotropic parameters. Secondly, the use of a more complete AVO approximation that accounts for common anisotropic effects helps to avoid the misinterpretation of hydrocarbon-related AVO signatures, which might result from the false positive effect of overlaying anisotropic shales above water-saturated sands.

The additional uplift in vertical details is provided by the a priori geological information infused in the inversion process. Information about facies thickness distributions and/or stratigraphic ordering rules reduce the solution space to only the stratigraphic relationships that can be supported by the geological deposition expected in the area. Well log data from the Montney formation was used to build a 1D model to illustrate and test these ideas. In this case, understanding the vertical heterogeneities within the Montney formation is a key factor in the design of horizontal well completions. Our results show, that even in the case of very thin, almost indistinguishable litho-facies but with slightly different anisotropic parameters, DPI is able to predict the vertical distribution of these facies with relatively high confidence levels.

Results and Conclusions

The results obtained from both synthetic and field data show how VTI-DPI minimizes the overprediction of hydrocarbon saturated reservoirs providing more realistic solutions. Moreover, the results show how VTI-DPI can accommodate facies models with a much higher vertical detail than its deterministic counterpart. In particular, for the offshore conventional reservoir VTI-DPI was able to correctly classify the false positives observed in the isotropic solution while preserving the true hydrocarbon predictions. In conclusion, allowing for more complex physics in the modeling of AVO responses not only allows for a more accurate representation of the field data but also for a correct facies identification and quantification of their probabilities.