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Petrophysical Seismic Inversion Applied to the Troll Field

A.J. van Wijngaarden, Hydro; T.J. Coleou, CGGVeritas; R. Ona and A. Norenes Haaland, Hydro; and P. Moliere, CGGVeritas

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Abstract

In this paper the application of petrophysical seismic inversion is described and the results for a case study on the western part of the Troll Field in the North Sea are shown.

The inversion method is driven by petro-elastic models. These models describe the transformation of porosity, fluid saturations and clay content to the elastic parameters for Pressure-wave velocity, Shear-wave velocity and density. The method uses updates of the fine-scale (1m) geological model in depth to make it fully compatible with pre-stack seismic measurements. The results are being used for infill drilling and for 4D inversion to determine the remaining oil in the thin oil leg.

The case study shows the importance of a correct petro-elastic model and the correct saturations for the oil and gas, specially for the low saturations of gas, that comes out of solution. In normal seismic the lithological changes in the oil leg are masked by the strong flat spot, which is caused by the GOC. But by using this petrophysical parametrization, the lithological variations within the thin oil leg can be visualized. The parametrization in petrophysical parameters gives also a possibility to do a fast implementation of “what-if” scenario.

Introduction

This project is a pilot study to apply this new methodology (Bornard *et al.*, 2005) on an offshore sandstone reservoir characterised in an existing fine-scale geomodel, with well-understood geological setting and good quality seismic data. It involved the Troll asset team and R&D groups from Hydro and CGG.

On the Troll West field, permeability is the main petrophysical variable that controls the oil production behaviour. In the geo-

model and for well planning purposes the sands in the Sognefjord formation are divided into two categories, namely Clean-sands and Micaceous-sands corresponding to different sorting and leading to different porosity distributions. The large contrast in permeability gives a nonuniform drainage, which is monitored by time-lapse seismic. An updated petrophysical model using the seismic could improve the geo-steering of well branches during drilling in the thin oil leg and the prediction of the remaining oil.

Petrophysical Seismic Inversion: Methodology

Unlike traditional seismic inversion techniques that solve for elastic properties in time, the Petrophysical Seismic Inversion (PetroSI) operates on rock properties in depth. The PetroSI workflow is illustrated in Figure 1. We start from an initial fine-scale geomodel defined from a 3-D stratigraphic grid in depth (left). A Petro-Elastic Model (PEM) is applied to calculate elastic properties in each cell of the geomodel from stored values of porosity, rock type and saturations (middle).

Angle-dependent reflectivity series are calculated from the elastic properties through the Zoeppritz equation at each trace location. The reflection coefficient series are then converted from depth to time using the velocities stored in the stratigraphic grid. Angle-dependent 3-D synthetics are finally generated by wavelet convolution (top-right in Figure 1). Perturbations of the properties of the geomodel are introduced using a simulated annealing algorithm to optimise the degree of match between the synthetic and the real angle stacks. After convergence, the final geomodel honours the observed seismic amplitudes, is consistent with the user-specified PEM and integrates inversion-based velocities that ensure coherence between the depth and time domains. It should be noted that changes in the initial model such as the small-scale distribution of rock type, or the modification of the PEM would lead to different solutions. The final models then represent alternative solutions consistent with the seismic data.

PEM Calibration

This step is critical. It reconciles different static measurements (cores, logs and seismic) obtained at different scales and different domains (depth and TWTime). The PEM is based on the Rock Physics Template obtained after comprehensive studies by Hydro (Avseth *et al.*, 2005). The use of the petro-elastic model establishes the necessary link between V_p , V_s and ρ .