

Semi-quantitative 4D seismic interpretation integrated with reservoir simulation: application to the Norne field

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"One important use of 4D seismic in particular is at the reservoir simulation model updating process. However, 4D seismic data have uncertainties related to non-repeatability, noise, imaging and interpretation."

Introduction

One important application of 4D seismic data is to support the reservoir simulation model updating process. This text summarizes the workflow developed in collaboration with the Heriot-Watt University and presented in Santos (2017), where simulated properties are converted to the seismic domain and then compared to real (observed) seismic. Mismatches between both datasets are then investigated, evaluating whether they are caused by a simulation model inaccuracy or by uncertainties in the actual seismic response.

Methodology

The black boxes from figure 1 describe a general workflow to achieve a 4D model-based seismic data interpretation. The seismic domain side includes a preliminary seismic interpretation to understand the character of the seismic, to assess its quality, and to identify the location of the key producing zones.

On the engineering domain side, we add the simulator results converted to the seismic domain (synthetic amplitudes) through simulation-to-seismic modelling (sim2seis) proposed by Amini (2014). The next step is a comparison between the observed seismic and the synthetic seismic response. Mismatches between the two datasets would ideally mean that the simulation model has inaccuracies and should be calibrated to the 4D seismic data. However, this is only the case for seismic data which is noiseless, perfectly acquired, processed and interpreted. The uncertainties inherent to these three stages demand a more thorough knowledge on the reliability of the seismic data prior to implementing a seismic history matching procedure. The blue boxes in figure 1 handle these uncertainties: a "false match" means the anomalies compared represent different physical effects. In the areas where "true matches" occur and the observed seismic data is reliable, we assume the simulation model is a good representation of the reservoir and does not need updating.

The workflow can be run in a loop, as indicated by the grey line in figure 1, until all the areas in the simulation model with mismatches caused by simulation model errors can be reviewed and updated (using high confidence seismic data).

Application

The methodology was applied to the Norne field benchmark case, described in Verlo & Hetland (2008). Production started in 1997 and the 3D seismic surveys available for this study have been acquired and 4D processed in 2001, 2003, 2004 and 2006.

Sim2seis x observed seismic comparison - area 1

The well B1-BH started production in January 2006. A neighbouring well B4-H produced between 1998 and May 2001, before the first seismic available. The oil-water-contact (OWC), provided with the Norne benchmark database, was interpreted using 4D seismic and is plotted in figures 2a to c. Figure 2a shows the seismic difference between 2006 and 2001 from a vertical section across these wells. The blue anomaly inside the black circle was interpreted as water replacing oil, which is in agreement with production data that showed water reached the well at the beginning of 2006 (figure 3). Sim2seis 4D differences do not show the same effect (black circle from figure 2b).

This means the simulation is incorrectly presenting no water breakthrough in this part (black circle from figure 2c). Confirmed by the water-cut curve (figure 3) that shows the simulation presents an incorrect water breakthrough and a lower water saturation rate, the seismic interpretation confidence level is high in this area. It is therefore recommended that the simulation model is updated to replicate this effect.

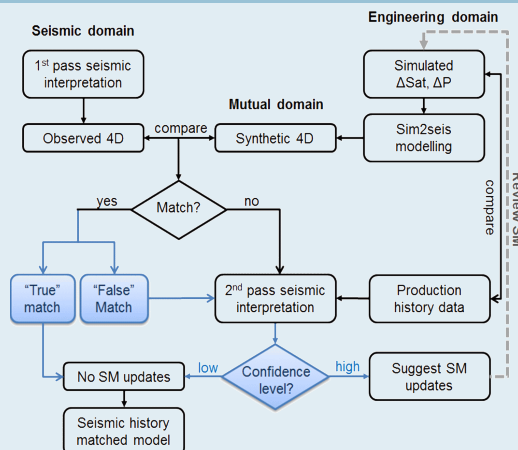
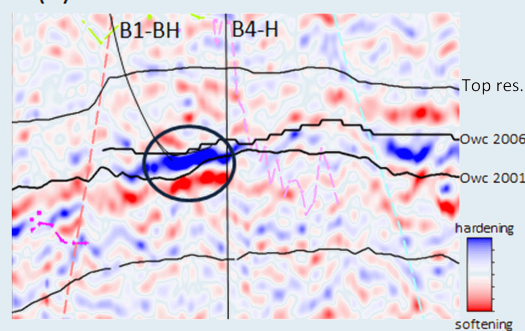
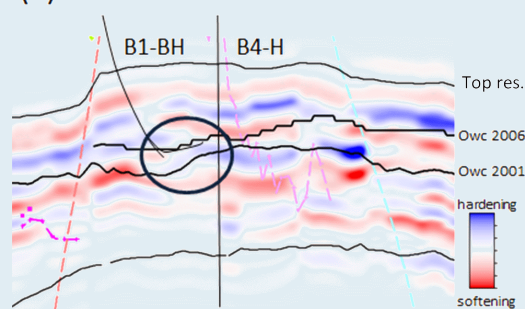


Figure 1: Seismic interpretation sequence (in black) and the addition of confidence check steps (in blue).

(a) Obs. 2006-2001



(b) Sim2seis 2006-2001



(c) ΔSw 2006-2001

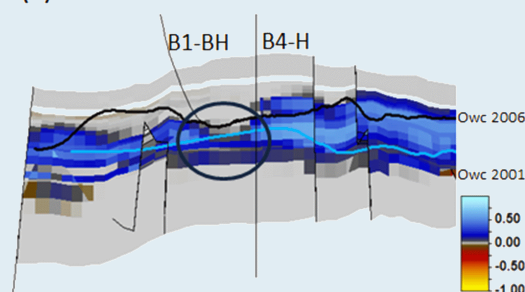


Figure 2: Observed seismic (a), Sim2seis (b), simulated water saturation (%) (c) 2006-2001 differences.

Sim2seis x observed seismic comparison - area 2

The well E-3CHT2 was open in May 2005. Production data from this well showed that the water breakthrough occurred two months later. Observed seismic difference between 2006 and 2004 (figure 4a), although considerably noisy, shows a continuous and consistent hardening (blue) effect related to the OWC rise in the section across this well. Sim2seis difference

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"This work demonstrated that integration between disciplines is required in order to properly interpret 4D data."

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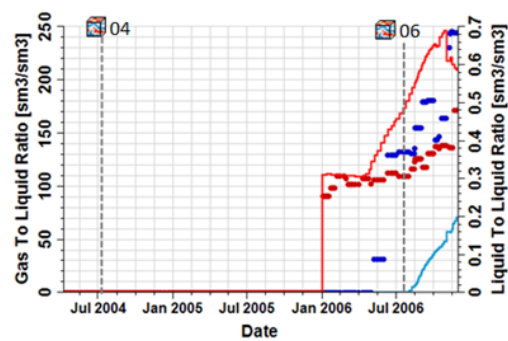


Figure 3: Gas-oil ratio (red) and water cut (blue). The solid lines are the simulation results and the circles are the historical data for the well B1-BH. The dotted lines represent the approximate seismic acquisition dates.

(figure 4b) shows the same blue anomaly, however as a result of a pore pressure decrease in two areas from the simulation model, pointed by the black arrows in 4c. The simulator's pressure behaviour in this example might not be correct, as indicated by the graphs from figure 5, where there is a clear mismatch between measured and simulated BHP data. For this case, we have classified the comparison as a "false match", as they represent different physical effects (OWC rise for observed seismic and predominantly depletion for sim2seis).

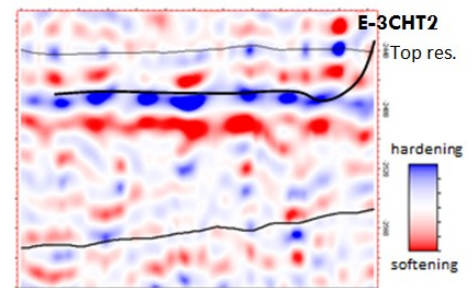
Final Considerations

This text shows a methodology that provides a 4D seismic semi-quantitative interpretation, identifying which information should be incorporated in the reservoir dynamic behaviour understanding process. The interpretation of the seismic data in both examples is classified as high-confidence, as no substantial amount of noise or competing effects are observed, in addition to being confirmed by well production data. However, it is important to highlight that there are other cases where confidence in seismic interpretation is low. The workflow proposes confidence level checks in order to evaluate which information should be used for this incorporation. The second example draws attention to the importance of a detailed analysis on the physical effects that cause the seismic anomalies, especially if an automatic seismic history matching procedure is to be implemented.

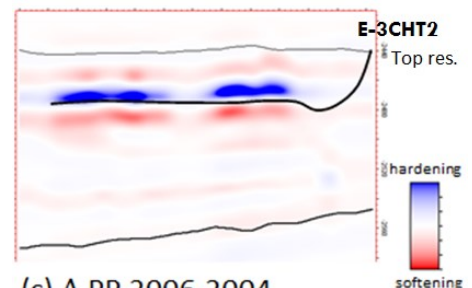
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- Santos, J. M. C. "Semi-quantitative 4D seismic interpretation integrated with reservoir simulation: application to the Norne field", Master Thesis, University of Campinas, 2017.
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(a) Obs. 2006-2004



(b) Sim2seis 2006-2004



(c) Δ PP 2006-2004

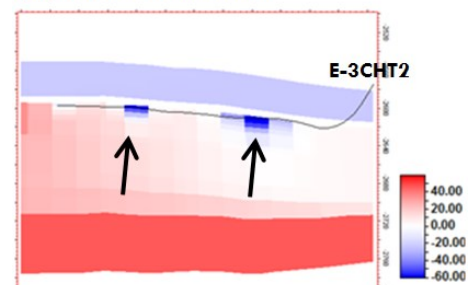


Figure 4: Observed seismic (a), Sim2seis (b) and simulated pore pressure (bar) (c) 2006-2004 differences.

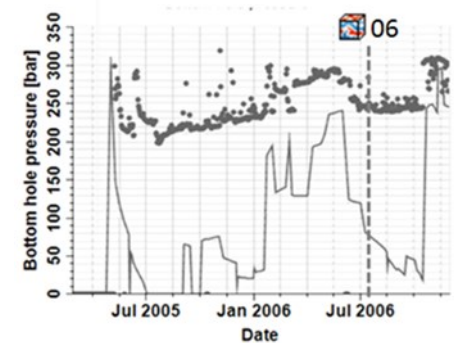


Figure 5: Simulated bottom-hole pressure (solid line) and well historical data (circles). The dotted line represents the approximate seismic acquisition date.

About author:

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