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Probabilistic Seismic History Matching Using Binary Images

Alessandra Davolio

Introduction

A key issue in seismic history matching (SHM) is to transfer data into a common domain: impedance, amplitude or pressure and saturation. In any case, seismic inversions and/or modeling are required, which can be time consuming. An alternative to avoid these procedures is using binary images in SHM as they allow the shape, rather than the physical values, of observed anomalies to be matched.

This text summarizes the paper of Davolio and Schiozer (2018), which presents the incorporation of binary images in SHM within the probabilistic history matching developed by UNISIM group. The application was performed with real data from a segment of the Norne benchmark case that presents strong 4D anomalies, including softening signals due to pressure build up. The binary images are used to match the pressurized zones observed in time-lapse data. Three history matchings were conducted using: only well data, well and 4D seismic data (4DS), and only 4DS. The results of the three cases are briefly presented here and deeply discussed in the full paper.

Methodology

This work applies the history-matching methodology presented by Maschio and Schiozer (2016), a probabilistic, iterative procedure that gradually updates the pdf for the attributes based on models that present the lowest data misfit. Although the applied procedure is very similar to "Method 3" of the aforementioned methodology, there are some adaptations, such as the addition of the seismic objective function.

4D seismic data and the corresponding simulation results are converted to binary images, for comparison. Thus, instead of using the usual quadratic error, we use the methodology proposed by Tillier et al. (2013) to measure the similarity between two binary images. The history-matching procedure was performed three times:

- WHM (well history matching): using only well data;
- SHM (seismic history matching): using both well data and 4D seismic data;
- OSM (only seismic matching): using only 4D seismic data.

Well data misfit is computed through the indicator NQDS also developed and presented in several UNISIM's works.

Dataset (Norne Field)

Four seismic surveys acquired in 2001, 2003, 2004, and 2006 were available. Assuming the base survey as 2001, strong 4D signals are observed in the 4D differences of the three monitors, as seen in Figure 1. For this work only the softening signals caused by pressure build-up is considered, as their interpretation is less uncertain.

For cases SHM and OSM, the binary maps generated from 4D seismic data (Figure 1d, e, and f) are compared with the binary maps generated from pressure estimates from the simulation models. Figure 2 illustrates this process.

The uncertainties considered in the three history matching procedures included multipliers of porosity and permeability, the transmissibility of all faults inside the segment, relative permeability, and 200 sets of petrophysical images.

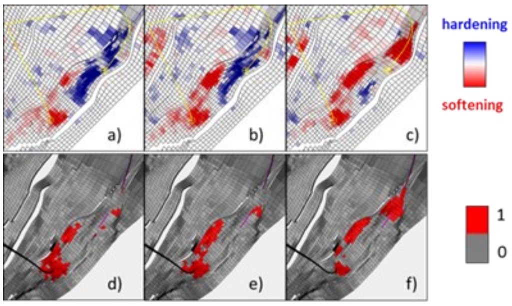

Figure 1: *4D seismic amplitude differences from surveys 2003-2001 (a), 2004-2001(b) and 2006-2001(c), and respective binary images (d, e, and f).*

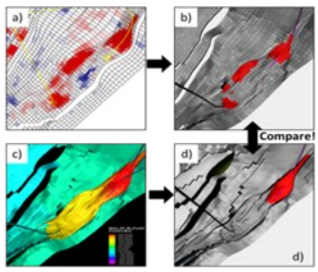

Figure 2: *Scheme comparing seismic and simulation data. The similarity of the amplitude changes due to pressure buildup (a) and the most pressurized zones from simulation (c) are measured by comparing the corresponding binary images (b and d).*

Results

For the three processes, the data mismatches improve gradually along the iterations for all considered objective functions. An interesting observation for the WHM results is that for the two first seismic monitors, the models of the final iteration are within the seismic objective function tolerance. This indicates that adding these binary maps is unnecessary. This is not the case for the last monitor, as only some models are within tolerance. This can be observed in Figure 3 which shows the binary images, for the last survey, for the best 25 models of WHM and SHM. Note that not all the images from the matched models of WHM match the expected behavior of the observed data while the opposite is observed for SHM. Besides providing models within the acceptance range using the binary images, the matched models from SHM present the same well matching quality as those from the WHM procedure. This is evidenced by the water rate curves (which is one of the most problematic objective functions) presented in Figure 4. These results support that for the SHM process the methodology satisfactorily generated models honoring not only well data, but also the expected binary images. The results of the OSM case show that the requirement of having only the pressurized zones (as indicated in Figure 1) does not guarantee that these models are consistent with well history data. Indeed, this case provided the worst results as it can be observed in Figure 4c.

"The results obtained in this work, with real data, encourage the application of the same approach in other cases."

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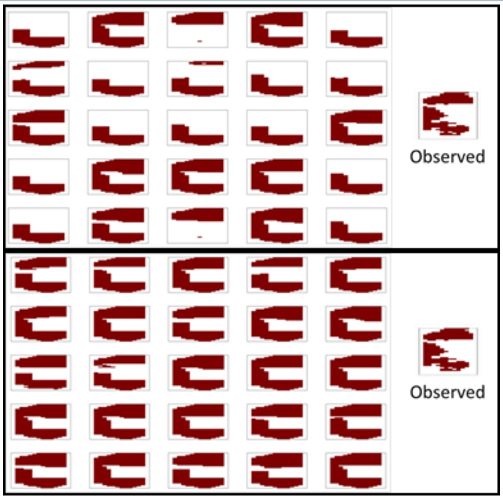

Figure 3: *Binary images considering the time-lapse difference 2006-2001 for the 25 best models from WHM (on top) and SHM (on bottom). The corresponding seismic binary image is shown on right.*

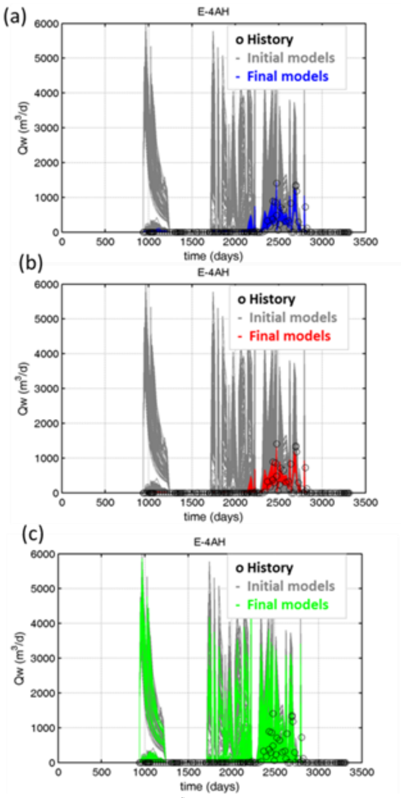

Figure 4: *Produced water rate for the cases WHM (a), SHM (b), and OSM (c).*

Conclusions

We found the history-matching methodology to be efficient using real data, and able to generate models that honor well data and binary maps in few iterations. The methodology is flexible regarding the inclusion of new objective functions, such as binary images, as shown here.

Results from the third procedure (OSM) presented very poor matches with well data. Therefore, only having a pressurized zone at the location observed from the 4D seismic data is insufficient to generate feasible models (especially for this case with complex pressure behaviors).

The two other procedures (WHM and SHM) were equally effective in matching well data. However, the SHM was advantageous because it also captured the expected dynamic behavior (pressurized zones) observed on 4D seismic data. The results obtained in this work, with real data, encourages the application of the same approach in other cases.

The use of binary images in seismic history matching can be a good alternative especially because it allows comparing data with different physical quantities as well as it avoids the use of a (uncertain) petro-elastic modeling. A possible drawback of such approach is the lack of sensitivity to coupled effects (caused by simultaneous fluid and pressure changes).

Another alternative to be further evaluated is the use of multi-level images. In this case different categories of 4D anomalies could be simultaneously matched, such as positive, negative and null zones.

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