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ABSTRACT

HISTORY MATCHING USING FINE SCALE 3D/4D SESIMIC HETEROGENITIES

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It is widely known that an integration of 3D/4D seismic data in reservoir characterization and modelling workflows is a potentially powerful tool. One of the many reasons is that seismic data distinguishes itself with high lateral resolution compared to a coarse cell scale in flow simulation process.
Conventionally, required time of computation constrains the scale of grid cell. This leads to a choice between time consuming fine scale grids and coarser grids with unsatisfactory representation of complex geological structures and of fluids flows. Furthermore, the link between geological model and the flow simulation model has more physical sense when using fine scale model.
Hereby is presented a novel workflow developed for a turbidite channel reservoir with complex structural and stratigraphic architectures. The workflow starts with the new algorithm of petrophysical inversion based on petro-elastic model (PEM) which offers a high quality distribution of static properties. Then the fine scale seismic lateral details allow locating small and meaningful connections/barriers within a reservoir. As soon as small heterogeneities are properly preserved and transferred into the dynamic model, the benefit appears in significant reduction of history matching phase. Finally, a validation of dynamic model and a history matching process are assisted by incorporation of time-lapse seismic data.

Introduction

In this paper the methodology allowing an appropriate integration of the seismic information within a flow simulation grid is presented. Herewith the fine scale features of static model are well preserved, having strong impact on dynamic simulations and history matching. The proposed workflow is based on the key-steps, as follows:

1. The algorithm of petrophysical inversion based on PEM to obtain 3D static properties distribution
2. Accurate seismic facies input within the refined simulation grid

3. An appropriate upscaling to the coarse simulation grid scale and a flow simulation
4. An *a posterior* validation of dynamic model and history matching based on 4D seismic attributes and production data

The workflow is applied on a sector of an off-shore field that comprising one water injection and one oil production wells.

Methodology

1. The algorithm of petrophysical inversion based on PEM

3D and 4D Petro-Elastic Model (PEM) can allow forward modelling of a seismic response from known petrophysical properties (Gosselin, 2003). The PEM application results in a seismic attribute which validity is checked and calibrated on well logs. The next stage is to solve an inverse problem and to obtain distributions of static properties (porosity, clay content and initial water saturation) from observed seismic attributes. For this purpose a new algorithm of inversion was developed to adjust modelled seismic attributes from PEM to observed data.

2. Accurate seismic facies input within the refined simulation grid

The petrophysical and dynamic properties (permeabilities) are defined utilizing core data and well logs and assumed to be constant per facies for simplicity. Then 3D facies propagation is performed based on well calibration and static properties obtained from the petrophysical inversion. Hence the information is integrated both on well and seismic scale.

3. An appropriate upscaling to the coarse simulation grid scale

The key advantage of the approach is the proper upscaling. The challenge here was to preserve sand channels communications and shaly barriers. In the case study, the sandy channels were characterized by flexuous shapes and minor scales compare to a coarse cell size. Therefore the use of conventional averaging and discrete upscaling techniques led to non-representative flow at coarse scale.
For these purposes a new discrete upscaling technique has been developed. Moreover, to keep the information about the directions of connectivity of sand channels in 3D seen by seismic, we introduce a new modelling property associated with the cell face.
The permeabilities have been upscaled using a specific pressure solver upscaling algorithm based on finite elements techniques (as used by Hadj Kacem, 2006). The flow simulation in this sector uses limit conditions of the full field model simulation. This full field was initially history matched using standard approach.

4. An *a posterior* validation of dynamic model and history matching based on 4D seismic attributes and production data

The fine scale 3D seismic information enables to highlight reservoir facies. In addition, 4D seismic data reflects a dynamic performance of reservoir. In the case study we took advantage of both types of information.

The dynamic performance of the static model built from seismic data was validated with the observed 4D attribute (figure1). First of all, the 4D attribute was upscaled to the coarse simulation grid of the sector model. Then interpreted anomalies in the 4D attribute were synchronized with pressure and saturation changes induced by production using PEM response. A history matching phase was reduced to a comparison between an interpretation of 4D anomalies and a flow simulation results on this sector model. As it turned out, the only parameter to be adjusted during history matching phase was vertical permeability. The history matched static and dynamic models in the sector model are inline with production data and time lapse seismic data (figures 2 to 4).

Conclusions

The deterministic methodology presented has been successfully applied to a real turbidite reservoir. The new methodology allowed preservation of fine scale heterogeneities and features of a complex reservoir in the coarse flow simulation model.
As a result, the reservoir model is consistent with both 3D and 4D seismic data.

References

Gosselin O., Aanonsen S. I., et al., History Matching Using Time-lapse Seismic (HUTS). SPE Annual Technical Conference and Exhibition, 5-8 October, 2003, Denver, Colorado

Hadj Kacem N., Berthet P., et al., Methodology for integration of small scale 3D/4D seismic features in reservoir simulations. Expanded Abstracts of EAGE 68th Conference & Exhibition, Abstract E032, 12-15 June, 2006, Vienna, Austria

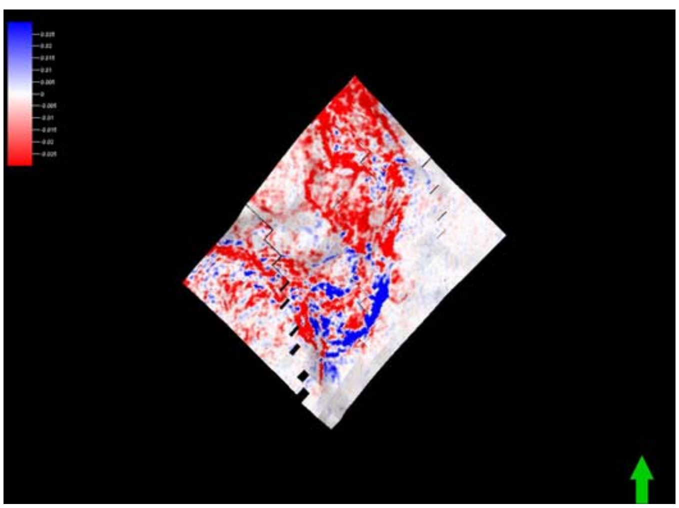

Figure 1 A 4D attribute difference between before and after first oil seismic vintages. 4D seismic anomalies: positive (blue) due to water injection from the Injector, negative (red) due to depletion around the Producer.

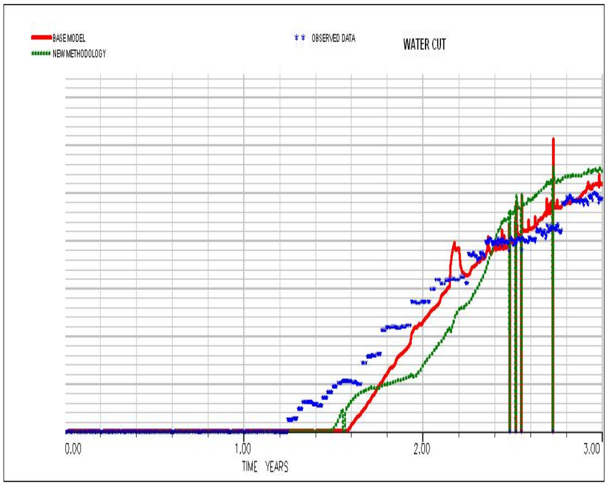

Figure 2. The results of the flow simulations: water cut in the Producer. The comparison of the results of simulations with full field model (red), new methodology model (green), and observed data (blue).

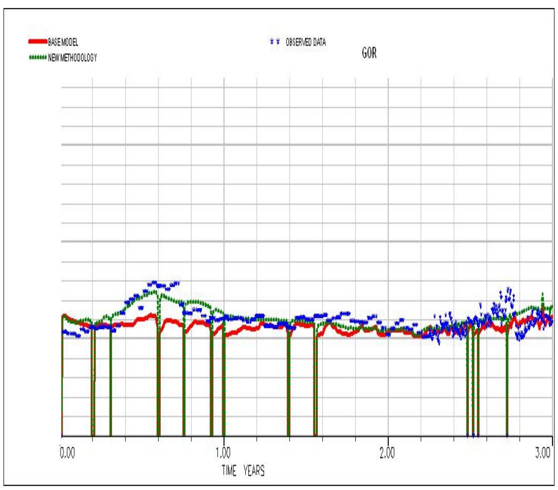

Figure 3. The results of the flow simulations: gas-oil ratio in the Producer. The comparison of the results of simulations with full field model (red), new methodology model (green), and observed data (blue).

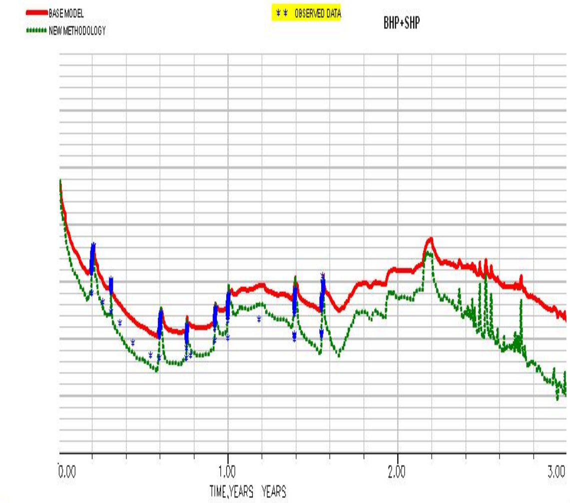

Figure 4. The results of the flow simulations: static and flow bottom hole pressures in the Producer. The comparison of the results of simulations with full field model (red), new methodology model (green), and observed data (blue).