P46

Optimizing Fluid-rock Properties in Compartmentalized Reservoirs By Using Dynamic and 4D Seismic Data

R. Villegas* (University of Leeds) & Q. Fisher (University of Leeds)

SUMMARY

In this work we develop improved constraints on fault areas and define methods for history matching using both production and 4D seismic constraints, which will provide a more robust basis for production forecasting. We propose improved workflows to change the fault areas into the simulation model specifically by modifying the relative permeability near the faults and by considering two phase flow together with the 4D seismic data results.

Recently several studies have been conducted to calibrate fault seal methodologies by incorporating geologically-reasonable fault rock properties into production simulation models, and then observing whether or not history matches are improved. In some cases, good history matches are obtained when only single-phase fault rock permeability values are incorporated into production simulation models (Jolley et al., 2007). In other cases, the relative permeability of faults is required to obtain a history match of production data (Zijlstra et al., 2007). However, since the history matching is an ill-posed problem, it does not have a unique solution such that the uncertainties always remain and further work is required to identify the circumstances in which it is advantageous to include multi-phase flow properties in production simulation models and in which single-phase fault rock properties will suffice.

In this work we evaluate the impact of fault properties on reservoir production by evaluating the impact on a manual history matching process of fault-compartmentalised reservoirs based on both production and 4D seismic data. We develop improved constraints on fault areas and define methods for history matching using both production and 4D seismic constraints, which will provide a more robust basis for production forecasting. We propose improved workflows to change the fault areas into the simulation model specifically by modifying the relative permeability near the faults and by considering two-phase flow (Manzocchi et al., 2002) together with the 4D seismic data results. We assume that the datasets correspond to reservoirs whose 4D seismic responses are primarily due to changes in fluid saturation. In order to modify the relative permeability data by including the 4D seismic it is necessary to carry out the pressure saturation inversion (Floricich et. al., 2005) of the model based on time lapse seismic and production data. The initial model proposed (allowing for generating new relative permeability trends) is:

$$Kr_{new} = C.\frac{\mu}{TRANS}\frac{\Delta Sw}{\Delta P} \ldots (1)$$

where Kr_{new} is the new relative permeability, C is the scaling value which in our case involves the prior values of absolute and relative permeabilities, $TRANS$ is the transmissibility of the fault (**Figure 1c**), ΔSw is the difference in water saturation at two different time steps (from 4D seismic seismic inversion, see **Figure 1a**, specifically the interval between the seismic surveys), and ΔP is the difference in pressure between two different time steps, see **Figure 1b**. By also using equation 1, we obtain a new estimation of relative permeability values as displayed in **Figure 1d**, the red line being the resulting relative permeability after including the 4D seismic data, and the blue line corresponding to the initial relative permeability information. To include this new relative permeability trend in the model, we define regions in the numerical model which are near the faults and which use the new relative permeability trends. This way we create regions with different mobility ratios considering the changes in saturation and pressure from 4D seismic. After changing the relative permeability in the way shown before, we compare the objective function which is defined as the data misfit between simulated and reference data. In this case a synthetic but realistic black oil reservoir is used which consists on 3 producer wells and 3 injector wells. The objective function is defined as a least square data misfit , $J = \sum_N (Q_W - Q_{W_{OBS}})^2$,where Qw is the simulated water production rate of the reservoir and Qw_{OBS} is the reference water production rate. This objective function was chosen because the reservoir does not have important changes in pressure.

After applying the relative permeability modification in the area near the faults considering 4D seismic information, the final model shows a better match, even though not significantly improving the data misfit. The initial cost value is 6.10, and the final cost value is 6.02 in the chosen units. This is due to the small increment in the relative permeability corresponding to the water, which makes it necessary to further increase the water mobility through the reservoir in the attempt to match the reference breakthrough.

In this work we show that the predicted saturation distribution within reservoirs can be even more sensitive to the different fault seal algorithms, which is used than to the data (such as fluid production rate and bottom-hole pressure evolution). The resulting improved history matching outcome provides a better basis for production forecasting, since the values of the objective function which controls the data misfit are reduced when incorporating the new relative permeability trend. Using this technique of history matching, we provide a geologically-consistent method for improving previous techniques to model fluid flow in compartmentalised reservoirs incorporating 4D seismic information.

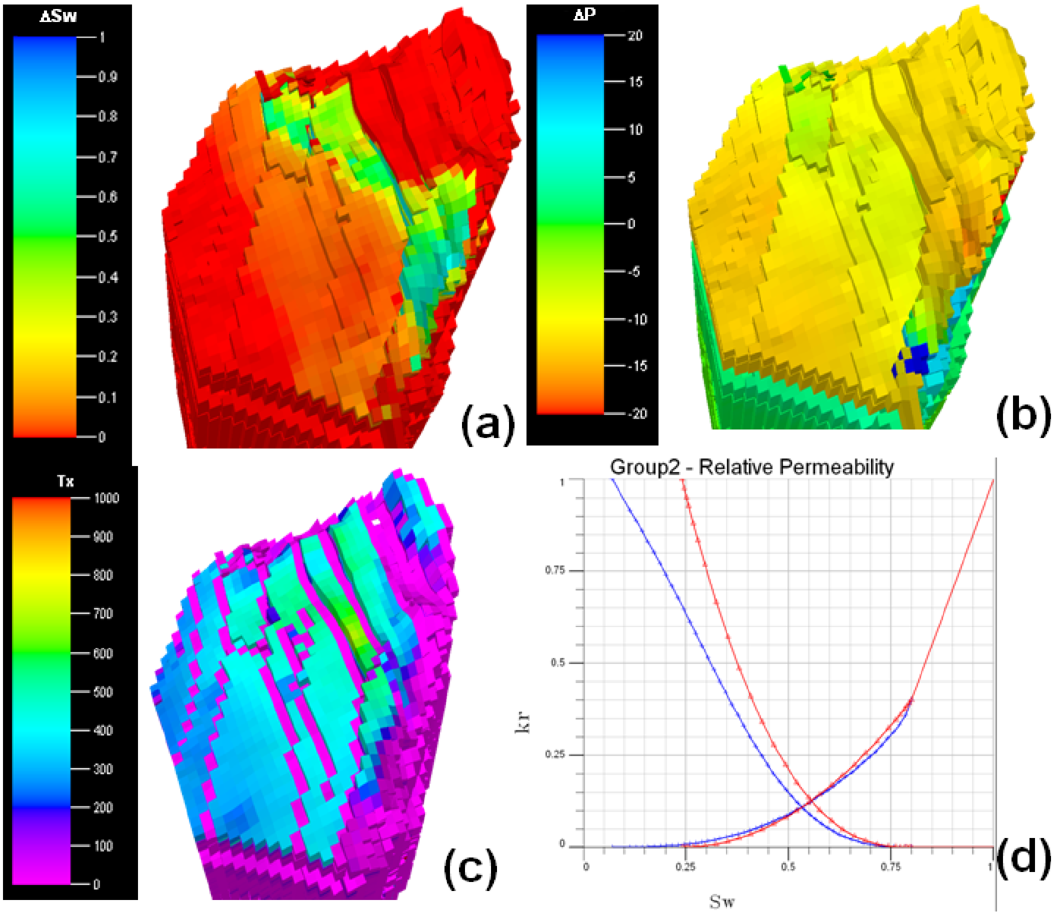

Figure 1 *First row: Changes in Saturation (left) and changes in Pressure (right). Second row: Transmissibilities in X direction (left) and relative permeability trends, (blue: original and red: new estimation).*

References

Floricich M., MacBeth C., and Staples R. [2005] An engineering-driven approach for separating pressure and saturation using 4D seismic: Application to a Jurassic reservoir in the UK North Sea: 75th Annual Meeting SEG, 2464-2467.

Jolley, S.J., Dijk, H., Lamens, J.H., Fisher, Q.J., Manzocchi, T., Eikmans, H. and Huang, Y. [2007] Faulting and fault sealing in production simulation models: Brent Province, northern North Sea. *Petroleum Geoscience*, 13, 321-340.

Manzocchi, T., Heath, A.E., Walsh J.J. and Childs, C. [2002] The representation of two-phase fault-rock properties in flow simulation models. *Petroleum Geoscience*, 8, 119–132.

Zijlstra, E., Reemst, P., and Fisher, Q.J. [2007] Incorporation of the two-phase flow properties of fault rocks into production simulation models of the Roliegend reservoirs. Geological Society, London, Special Publication, 292, 295-308.