F02

Improved Implementation of Fault Seal Analysis in Reservoir Simulation

S.R. Freeman* (RDR Ltd), S.D. Harris (RDR Ltd), R.J. Knipe (RDR Ltd), K. Wood (RDR Ltd) & V.S. O'Connor (RDR Ltd)

SUMMARY

A major current limitation in the application of fault seal workflows in the reservoir simulation process is the inability to interactively update fault properties to fit to dynamic data. Often significant effort is expended in the generation of viable fault properties and geometries but this initial estimate will often be in error (due to the natural variability of the systems and the inaccuracy with which we can define the various parameters). When the reservoir engineers fail to generate a history match from this initial estimate the lack of geologically driven editing tools mean that often the geologically derived fault properties are replaced by uniform, fault wide single values which are editable. This major loss of data and understanding is due in part to a lack of editing tools available to the reservoir engineer that honors the geological form of the data. Providing tools that can allow interactive creation and editing of fault properties should allow for a far greater utilization and improved application of fault seal analysis in the simulation process. This enhanced integration of geological and reservoir engineering knowledge should ultimately lead to better management of the reservoir.

In this contribution we present a new technique to dynamically generate and edit fault transmissibilities to help improve the integration of fault seals into simulation models. This technique provides the reservoir engineer with new tools to dynamically update the fault transmissibilities in a geologically meaningful way during the history matching process. This should allow for a step-change in the incorporation and utilization of fault seal data within simulation workflows.

Faults within reservoir simulation models can have a major impact on the modelled performance of a reservoir. Accurately assessing the transmissibility of faults can be a key factor in effectively managing a given resource. Unfortunately, as with much in geology, geophysics and reservoir engineering, there is considerable uncertainty in the estimation of the various geometries and properties involved in the determination of transmissibilities. A second challenge results from the cross-disciplinary nature of the problem. Typically geologists are best placed to define the framework within which the fault connections and transmissibilities (a combination of both fault permeabilities and fault thicknesses) can be estimated, but it is the reservoir engineers that will eventually work with the data and they require tools to modify the result in order to develop matches to historical production data. Often considerable effort is spent in developing a geological model that allows the fault connections and transmissibilities to be estimated, but this typically 'one-shot' estimate often does not match the production data. The reservoir engineer is then faced with the conundrum that the fault properties provided do not match the dynamic data so cannot be used despite the knowledge that the properties are based on a scientific process. Also these geologically derived properties cannot be easily varied. The only option typically available to the reservoir engineer is to replace the geologically driven fault property predictions with a constant value across the fault that can be modified 'on the fly' (within the simulator or reservoir modelling package) to eventually allow some form of history match to be achieved. This situation, which is common, is clearly less than optimal and often frustrating for all involved. The potential implications for resource management are considerable.

Tools are therefore required that allow the geologist to define the workflow, the range in solutions that are probable and also to define the potentially complex interactions between those processes (e.g. realistic limits for the potential variables, such as fault clay content). The reservoir engineer can then use these limits to produce a range of solutions. Those solutions and workflows need to be accessible to the reservoir engineer in a manner that is intuitive to use. The resulting fault transmissibilities need to be dynamically editable by the reservoir engineer in a way that honours the geological relationships defined by the geologist but also allows the dynamic data to be matched. This tool therefore needs to occur within a system that handles both the geological and reservoir engineering data and can run the simulator to develop real-time feedback loops. The system also needs to allow a strong component of dynamic interaction by the user with the various different datasets (geological and reservoir engineering).

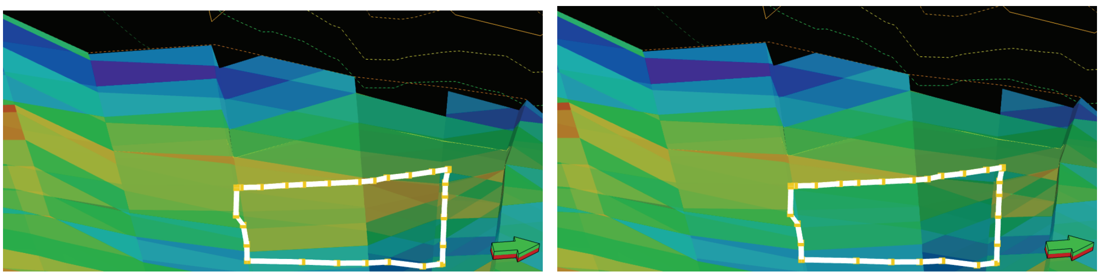

Figure 1 *Left: Original effective cross-fault transmissibility and editing area. Right: Edited effective cross-fault transmissibility. Hotter colours show higher cross-fault transmissibility. The editing has reduced the local cross-fault transmissibility while retaining the geological form to the data within the editing area.*

In this contribution we present a new solution produced by the authors within Schlumberger's Petrel^{TM} software that allows this process to occur. There are a number of key steps involved in the workflow and a range of relationships and uncertainties that need to be incorporated to effectively capture the likely range in fault properties. These steps typically include: (i) the estimation of the host clay content distribution through the reservoir; (ii) the estimation of the fault clay content using fault clay mixing and clay smearing algorithms; (iii) the estimation and application of a fault clay to fault permeability transform function; (iv) the estimation of the fault rock thickness (typically from fault displacement); and (v) the computation of the fault transmissibility and transmissibility multipliers for the faults. For a given reservoir stratigraphic type, deformation and burial history there are specific relationships that are more likely than others. These individual steps each have natural variability and uncertainty ranges, which the geologist can define. These combine to define a set of potentially valid solutions. It is these solutions that need to be accessible in a straightforward manner to the reservoir engineer.

Rather than developing a single solution, a set of solutions and a technique to manipulate them in a manner that is consistent with the geological relationships is required. Given that a number of the key parameters can be pre-computed, the application of modifiers to the input parameters and the re-calculation of the final transmissibility predictions can be conducted dynamically within the software in real-time.

As well as the computational issues there are also visualization challenges. To allow the user to vary the properties in a meaningful way they need to be able to see the data in a form that is closely related to the impact that it is likely to have within the simulator. The effective cross-fault transmissibility (ECFT) is one potential solution (see Figure 1). This property is the total transmissibility of the host rock on one side of the fault, the fault rock and the host rock on the other side of the fault, all normalized to a constant length scale (Freeman et al., 2008). For the same pressure differential, mobility and phase there should be a linear relationship between the ECFT and the fluid flow across the fault. If the user visualizes and modifies this parameter then there should be a clear link between the modification process and the resulting impact on cross-fault fluid flux. This should therefore lead to an effective editing process and hence a rapid generation of the required result. The modification process can be run in tandem with real-time streamline simulation. This therefore allows for a dynamic interpretation environment that can converge on a solution far faster than the traditional approach, and is likely to lead to a better predictive model.

Conclusions

Many technological and conceptual advances in the field of fault seal analysis have been achieved over the last decade. A far better understanding of the range in fault properties has been documented and methods to predict those properties have improved. Currently, the effective implementation of this knowledge is lacking. The creation of 'one-shot' estimates of fault transmissibilities and connections restricts the application when the data is passed to the simulator. Reservoir engineers require tools that allow them to be able to modify and update the fault properties (both geometric and petrophysical) in a manner that can both honour the geological limitations of the system and allow a match to the dynamic data. In this contribution we present a system that allows that to occur and also offers a way to decrease the time taken to produce a history match. This hopefully facilitates an improved integration of both the geological and engineering knowledge in the simulation model and will hence lead to better reservoir management.

References

Freeman, S. R., Harris, S. D. and Knipe, R. J. [2008]. Fault seal mapping—incorporating geometric and property uncertainty. In: Robinson, A., Griffiths, P., Price, S., Hegre, J. and Muggeridge, A. (eds), *The Future of Geological Modelling in Hydrocarbon Development.* The Geological Society, London, Special Publications, **309**, 5–38.