B03

Multi-phase Flow Properties of Fault Rocks - Implications Prediction of Across-fault Flow During Production

Q.J. Fisher* (University of Leeds), S. Al-Hinai (PDO), C. Gratonni (Rock Deformation Research Limited) & P. Guise (Rock Deformation Research Limited)

SUMMARY

Here we present new data on the relative permeability and capillary pressure of fault rocks as well as the stress dependency of relative permeability. The high capillary pressures and low relative permeability of some well lithified cataclastic faults helps explains why some Rotliegend reservoirs in the Southern North Sea are so severely compartmentalised by faults. The low capillary pressure and high relative permeabilities of poorly lithified phyllosilicate-framework fault rocks may explain why it is often possible to obtain good history matches of production data from faulted Brent-type reservoirs without incorporating the multiphase flow properties of fault rocks into simulation models.

The multi-phase flow properties of some samples are highly stress dependent even during elastic deformation. These new data suggest that it may be necessary to take into account the stress-dependence of fault rock flow properties when modelling across-fault fluid flow in compartmentalised petroleum reservoirs.

Abundant data are now available on fault properties such as the absolute permeability (i.e. single-phase) of fault rocks and fault thickness. These data allow transmissibility multipliers to be calculated that can be applied to grid block faces adjacent to faults within simulation models to account for the effects of faults on fluid flow (e.g. Manzocchi et al., 1999). In many cases, transmissibility multipliers calculated from these new data appear to improve history matches of production data (e.g. Knai and Knipe, 1998; Jolley et al., 2007). In other cases, transmissibility multipliers calculated from absolute permeability values appear to overestimate fault transmissibility; potentially because the multi-phase flow properties (capillary pressure and relative permeability) of fault rocks have not been taken into account (e.g. Al-Hinai et al., 2008; Zijstra et al., 2007). Recently, a significant effort has been made to make the first ever analyses of the multi-phase flow properties of fault rocks. These new results suggest that failure to take into account the multiphase flow properties can result in an overestimation of the transmissibility of some cataclastic faults by several orders of magnitude (Figure 1). When incorporated into production simulation models these new results help explain the extent of fault compartmentalisation in Rotliegendes reservoirs where cataclastic faults are abundant (e.g. Al-Hinai et al., 2008; Zijstra et al., 2007). The observation that in some circumstances it seems unnecessary to take into account multi-phase flow behaviour of fault rocks to achieve an history match may reflect the lack of continuity of low permeability fault rocks or the fact that some poorly lithified fault rocks have low capillary entry pressures and high relative permeabilities (Figure 2) under reservoir conditions.

Laboratory studies have also been undertaken to measure the stress sensitivity of the absolute and relative permeability of fault rocks and their analogues. The relative permeability of some samples appears highly stress dependent (i.e. reducing by a factor of around 20 as effective stress is increased by 2000 psi). These results suggest that accurately modeling across-fault flow in compartmentalized reservoirs may require the stress-dependence of the single and multi-phase flow properties of fault rocks to be incorporated into production simulation models. In some situations it may be relatively easy to estimate variations of reservoir stresses during production. In other situations, it may be necessary to couple production simulation models to geomechanical models to estimate the fluid behaviour of faults during production.

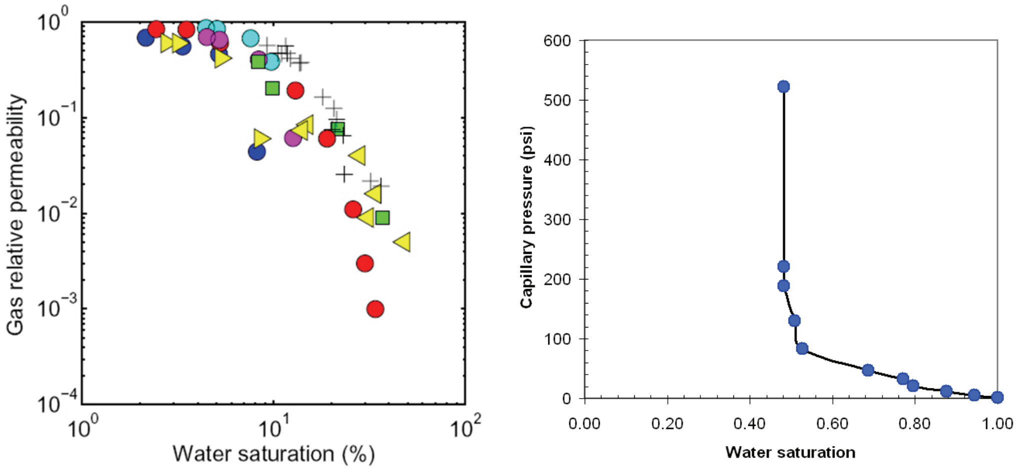
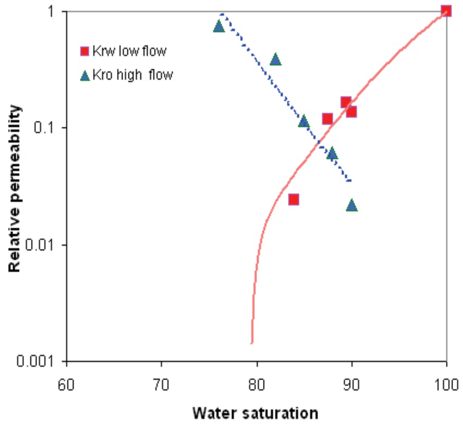


***Figure 1** Relative permeability (a) and capillary pressure b) data from a cataclastic fault from near Hopeman, Scotland.*



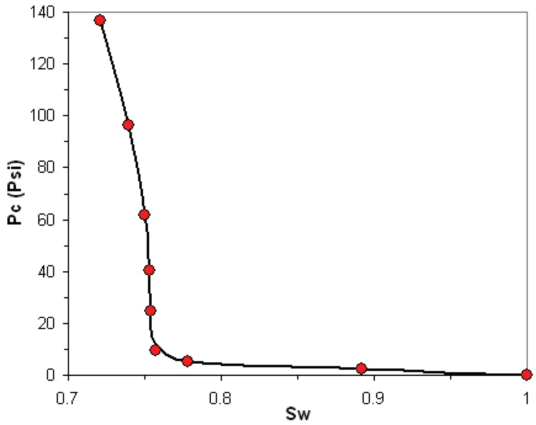


***Figure 2** Relative permeability (a) and capillary pressure b) data from a poorly lithified phyllosilicate-framework fault rock.*

References

Al-Hinai, S., Fisher, Q.J., Al-Busafi, B., Guise, P., and Grattoni, C.A. [2008] Relative Permeability of Faults: An Important Consideration for Production Simulation Modelling. *Marine and Petroleum Geology*, 25, 473-485.

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.

Knai, T.A. & Knipe, R.J. [1998] The impact of faults on fluid flow in the Heidrun Field. . *In*: Jones, G., Fisher Q.J. & Knipe, R.J. (eds) *Faulting and Fault Sealing in Hydrocarbon Reservoirs*. Geological Society, London, Special Publications, 147, 269-282.

Manzocchi, T., Walsh, J.J., Nell, P. & Yielding, G., [1999] Fault transmissibility multipliers for flow simulation models. *Petroleum Geoscience*, 5, 53–63.

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. In Jolley et al., (Eds) *Structurally Complex Reservoirs*. Geological Society, London, Special Publication, 292, 295-308.