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Numerical-Simulation-Based Determination of Relative Permeability in Laminated Rocks

Mohammad H Sedaghat (1), Kirill Gerke (1), Siroos Azizmohammadi (2), and Stephan Matthai (1)

(1) Department of Infrastructure Engineering, The University of Melbourne, Melbourne, Australia, (2) Department of Petroleum Engineering, Montan University of Leoben, Austria

Reservoir simulation using the extended Darcy's law approach requires relative permeability curves derived either via analytic saturation functions (Corey models etc.) or from special core analysis (SCAL). Since such experimental exploration of the space of influential parameters (pore geometry and wettability) is costly and time consuming, establishing ways to extract ensemble relative permeability from numerical simulation, kri, over the entire range of water saturation is highly desirable.

Recent work has highlighted that the shape of relative permeability strongly depends on the balance between viscous, gravitational, and capillary forces. Our work focuses on finding accurate ways to compute ensemble kri(sw) for layered rocks when both capillary and viscous forces are strong. Two methods are proposed: an unsteady state saturation variation (USSV) method and a steady state saturation variation (SSSV) technique. To evaluate these approaches, SCAL data was extracted numerically from a real mm-scale layered sample. Results obtained with a Finite Element-Centered Finite Volume (FECFM) simulator, suggest that either of the approaches work significantly better than conventional unsteady state and JBN (Johnson-Bossler-Naumann) methods. Also, investigating saturation and velocity profiles within the sample indicates that bed-by-bed variations in wettability influence the flow pattern along/across interfaces making equipermeable layers behave like zones with different flow velocity. This dramatically challenges conventional relative permeability models and is addressed in terms of a new variable called relative permeability index.