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Multi-GPU Accelerated Simulation of Dynamically Evolving Fluid Pathways

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Fluid flow in porous rocks, both naturally occurring and caused by reservoir operations, mostly takes place along localized high permeability pathways. Pervasive flooding of the rock matrix is rarely observed, in particular for low permeability rocks. The pathways appear to form dynamically in response to the fluid flow itself; the amount of pathways, their location and their hydraulic conductivity may change in time.

We propose a physically and thermodynamically consistent model that describes the formation and evolution of fluid pathways. The model consists of a system of equations describing poro-elasto-viscous deformation and flow. We have implemented the strongly coupled equations into a numerical model. Nonlinearity of the solid rheology is also taken into account.

We have developed a fully three-dimensional numerical MATLAB application based on an iterative finite difference scheme. We have ported it to C-CUDA using MPI to run it on multi-GPU clusters. Numerical tuning of the application based on memory bandwidth throughput allows to approach hardware peak performance.

Conducted high-resolution three-dimensional simulations predict the formation of dynamically evolving high porosity and permeability pathways as a natural outcome of porous flow coupled with rock deformation.