A GFEM Framework for Reservoir Simulation of Unconventionals

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Abstract: Projections through the year 2040 maintain that approximately 70% of domestic energy consumption will come from subsurface liquid and gas resources. Two-thirds of the production of those resources will come from tight (low permeability) or "unconventional" formations, where reservoir fluids are extracted through complex hydraulically induced and/or natural fracture networks. These reservoirs yield low extraction efficiencies that are often less than 6%. While engineers have made improvements over the last decade through trial and error, it is clear that a basic science gap stands in the way of further improvements that must be addressed to understand how and why enhanced recoveries are being realized.

The current generation of computational models and software used to simulate subsurface fluid transport, while experiencing continuous upgrades in the flow physics (e.g., compositional mass balances, flash calculations, advanced constitutive models for relative permeability, and capillary pressure), are little changed from a computational-methods and software engineering standpoint from simulators developed 40 years ago. New models that incorporate multiscale features into the numerical approximation, are fully coupled with sophisticated multiphysics (e.g., thermal, geomechanics), exploit the upcoming generation of exascale computers with their heterogeneous architecture and differing paradigms of parallelization in a performance portable way, and use of agile software development strategies to allow for future improvements in physics and numerics are crucial to enhance scientific understanding of unconventional reservoirs.

To address the shortcomings of the current computational models related to subsurface fluid flow in unconventional reservoirs, we propose the following integrated research goals: 1) development of a generalized finite element method, based on partition-of-unity concepts, that can embed multiscale physics and heterogeneous physical properties into the approximation spaces for coupled subsurface fluid flow and deformation mechanics; 2) agile software development, building from the DOE open source framework Trilinos, that facilitates arbitrary partition-of-unity approximation spaces and performance portable algorithms targeting heterogeneous architectures and exascale high-performance computers.

The impact of the proposed research will be an improved understanding of fluid flow in unconventional reservoirs that will provide for improved predictions, physical insight, and decision making for regulatory measures, environmental impact, and resource and water stewardship. Additionally, the newly developed models will be applicable outside of unconventional reservoirs (e.g., in enhanced geothermal energy applications, contaminant transport in fractured aquifers).