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Modelling fully-coupled Thermo-Hydro-Mechanical (THM) processes in fractured reservoirs using GOLEM: a massively parallel open-source simulator

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Utilization of the underground for energy-related purposes have received increasing attention in the last decades as a source for carbon-free energy and for safe storage solutions. Understanding the key processes controlling fluid and heat flow around geological discontinuities such as faults and fractures as well as their mechanical behaviours is therefore of interest in order to design safe and sustainable reservoir operations. These processes occur in a naturally complex geological setting, comprising natural or engineered discrete heterogeneities as faults and fractures, span a relatively large spectrum of temporal and spatial scales and they interact in a highly non-linear fashion. In this regard, numerical simulators have become necessary in geological studies to model coupled processes and complex geological geometries. In this study, we present a new simulator GOLEM, using multiphysics coupling to characterize geological reservoirs. In particular, special attention is given to discrete geological features such as faults and fractures.

GOLEM is based on the Multiphysics Object-Oriented Simulation Environment (MOOSE). The MOOSE framework provides a powerful and flexible platform to solve multiphysics problems implicitly and in a tightly coupled manner on unstructured meshes which is of interest for the considered non-linear context. Governing equations in 3D for fluid flow, heat transfer (conductive and advective), saline transport as well as deformation (elastic and plastic) have been implemented into the GOLEM application. Coupling between rock deformation and fluid and heat flow is considered using theories of poroelasticity and thermoelasticity. Furthermore, considering material properties such as density and viscosity and transport properties such as porosity as dependent on the state variables (based on the International Association for the Properties of Water and Steam models) increase the coupling complexity of the problem. The GOLEM application aims therefore at integrating more physical processes observed in the field or in the laboratory to simulate more realistic scenarios. The use of high-level nonlinear solver technology allow us to tackle these complex multiphysics problems in three dimensions. Basic concepts behing the GOLEM simulator will be presented in this study as well as a few application examples to illustrate its main features.