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Numerical investigation of coupled thermo-hydro-mechanical (THM) subsurface processes: importance of thermal effects and pressure diffusivity on post-injection seismic events

Khashayar Khezri (khashayar.khezri@minesparis.psl.eu)
Supervisors: Dominique Bruel, Emad Jahangir & Murad Abuaisha

Background

- Enhanced Geothermal Systems (EGS) accesses heat sources deeper in the Earth's crust, making geothermal energy viable in regions lacking active tectonic activity and broaden geothermal energy production to diverse geographical areas
- Induced seismicity, a consequence of EGS, arises from creating interconnected fractures to boost system efficiency
- One of the unresolved issues in studying induced seismicity in EGS is the occurrence of post-injection or delayed induced seismicity and the underlying processes driving this phenomenon
- Understanding delayed induced seismicity in EGS is crucial due to its severity post-injection, often surpassing seismic events during injection
- Limited understanding of induced seismicity pose risks to EGS efficiency and safety, impeding widespread geothermal utilization

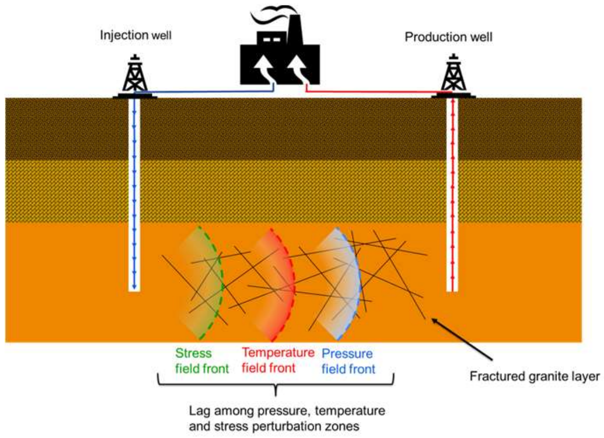

Figure 1: Asynchronous diffusion of temperature, pressure, and stress perturbation zones

Approach

Thermo-Hydraulic (TH) Model
- Develop a coupled TH model of a geothermal system

Fracture Incorporation
- Find efficient methods for incorporating fractures into TH model and define parameters which represent network properties (figure 2&3)

Parametric Study
- Study the impact of hydraulic, thermal and properties, on pressure and temperature diffusion

(TH+M) Model
- Expand the model to include mechanical processes, creating a robust coupled THM model of EGS formations

Model Validation
- Validate the model using existing laboratory data or analytical solutions

Seismic Event Analysis
- Investigate the delay and severity of induced seismic events under various initial stress and boundary conditions

Aim

In EGS, temperature, pressure, and stress perturbation zones diffuse asynchronously in different directions (figure 1), influenced by fracture network properties [1]. The combination of pressure and temperature variations in fractured rock formations can induce seismic activity, and the lag between their diffusion somehow leads to delayed induced seismicity. Previous research predominantly focused on pressure's role in delayed seismic events [2]. This study aims to advance understanding by modeling THM coupling processes, examining how pressure and temperature jointly influence stress fields within fractured rock and trigger delayed induced seismicity.

Initial Results

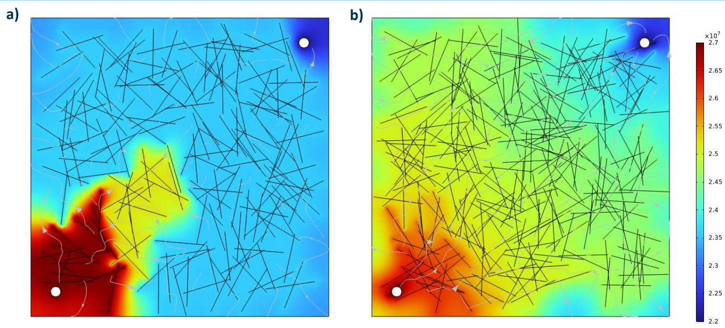

Figure 2: Pressure distribution in two different fracture networks with different connectivities. Percolation number is used in this study as a connectivity criteria [3]. (a) Non-connected fracture network with 200 fractures and percolation number of 5.55<5.8. (b) Connected fracture network with 300 fractures and percolation number of 8.33>5.8.

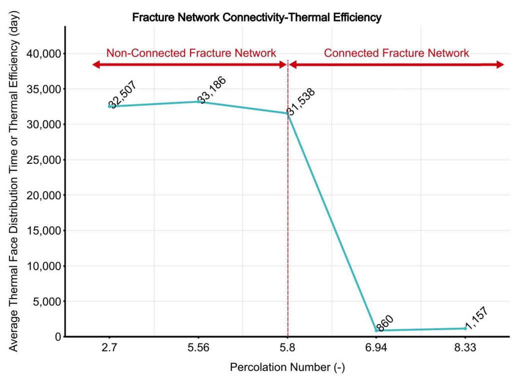

Figure 3: Effect of fracture network connectivity on average thermal face pace in domain

Acknoweldgement

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