The importance of local thermal non-equilibrium in the modeling of a fractured hot dry rock reservoir

Rachel Gelet, Benjamin Loret

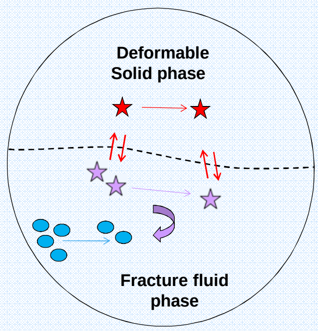
The importance of local thermal non-equilibrium in the modeling of a fractured hot dry rock reservoir

Rachel Gelet[(1)], Benjamin Loret[(2)]

Abstract Thermal recovery from a HDR reservoir, viewed as a deformable fractured medium, is investigated with a focus on the assumption of local thermal non-equilibrium. The numerical model is used to investigate the coupled thermo-hydro-mechanical behavior of the Fenton Hill site. The time profile of the outlet fluid temperature displays a double-step pattern, a feature which is interpreted as characteristic of established local thermal non-equilibrium.

The constitutive model uses a two-phase mixture and accounts for:

- ✓ Generalized diffusion
  - Hydraulic (Darcy)
  - Thermal (Fourier)
- ✓ Thermal convection
- ✓ Heat transfer



The significant contribution is the local thermal non-equilibrium

☆ ≠ ★

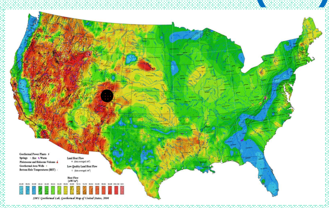
Characteristic times

$t_{\text{Fourier,frac.}}$ < $t_{\text{Fourier,solid}}$ < $t_{\text{Convection,frac.}}$ < $t_{\text{Darcy,frac.}}$

10 000 years < 1 500 years < [2 days – 7 years] < 1 hour

- Large difference in characteristic times between thermal diffusion in the solid phase and convection in the fluid phase
- ➢ Local thermal non-equilibrium is required to accurately represent the overall thermo-hydro-mechanical behavior
- ➢ The thermally induced effective stress will trigger thermal shrinkage across the body of the reservoir that may lead to permeability change and fluid loss

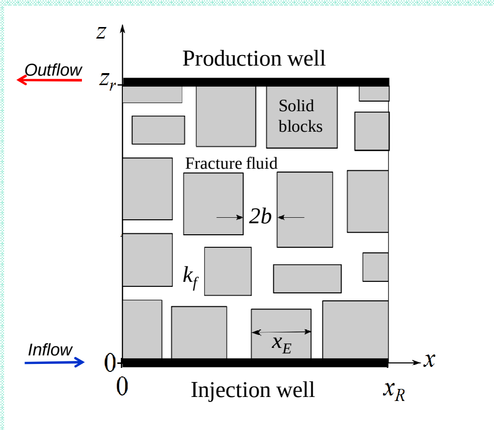
Site: Fenton Hill (US)



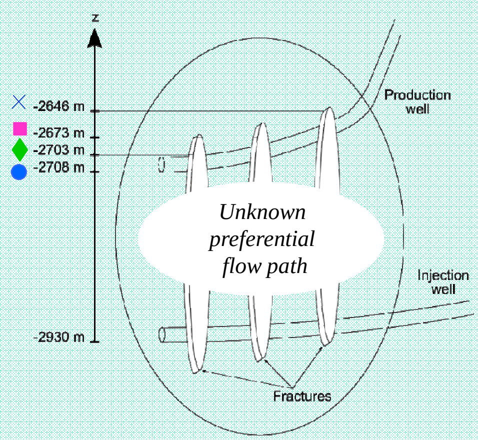
FE Simulation tools

- SUPG method
- Non-linear analysis treated with a Newton-Raphson algorithm
- Fortran language

Numerical setup

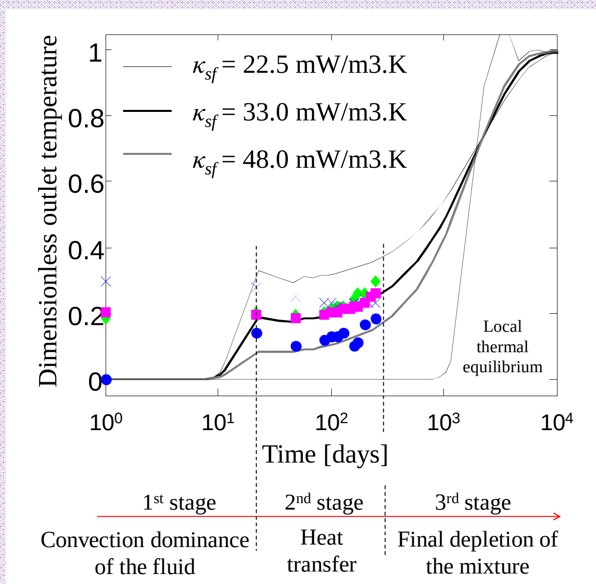


Compared with experimental data



THM coupled Results: relative temperature outlet versus time along the production well:

- Three parameters of the model are calibrated, namely the permeability k_f = 8.0 mD, the porosity n_f = 0.005 and the specific inter-phase heat transfer coefficient κ_{sf} = 33.0 mW/m^3.K
- Three stages characteristic of local thermal non-equilibrium are identified
- Local thermal non-equilibrium is characterized by a double step curve, while local thermal equilibrium is recognized by a single-step pattern



Summary

- Numerical results compare well with experimental ones
- The thermal drawdown curve is characterized by three stages, characteristic of local thermal non-equilibrium

Perspectives

Start experimental CHM and THM measures on real samples (ANR project in development)

(1) Laboratoire GeM, Université de Nantes, ECN, CNRS, BP 92101, 44321 Nantes Cedex 3, France
(2) Laboratoire Sols, Solides, Structures – Risques, Université de Grenoble, B.P. 53X, 38041 Grenoble Cedex, France

rachel.gelet@univ-nantes.fr