Thermo Hydro Mechanical modeling of hydraulic stimulation in a deep geothermal reservoir

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1. MOTIVATION

Geothermal energy production from deep hot rocks requires a high permeability heat exchanger in order to achieve a cost-competitive power generation. Hydraulic stimulation of geothermal reservoir is widely used to enhance the permeability of naturally fractured rocks. This procedure usually triggers microseismic events, which may sometimes compromise the continuation of the project (Majer *et al.*, 2007; Cornet *et al.*, 1997).

This induced seismicity is mostly governed by hydro-mechanical processes; however, thermal effects may also play a key role in the mechanical behavior (De Simone *et al.*, 2013). Understanding this mechanisms and how they are affected by the *in situ* conditions is important to properly design and manage geothermal stimulation and operations.

2. OBJECTIVE

An essential topic in geothermal reservoir stimulation design is the characterization of geometry and properties of the geological system. Fault zones involved in the stimulation processes are generally composed by a fault core, consisting of low-permeability gouge, surrounded by a damage zone, which is a wider microfractured region altered by large deformations (Faulkner *et al.*, 2010; Wibberley *et al.*, 2008). The higher permeability of the damage zone makes it to act as a flow path.

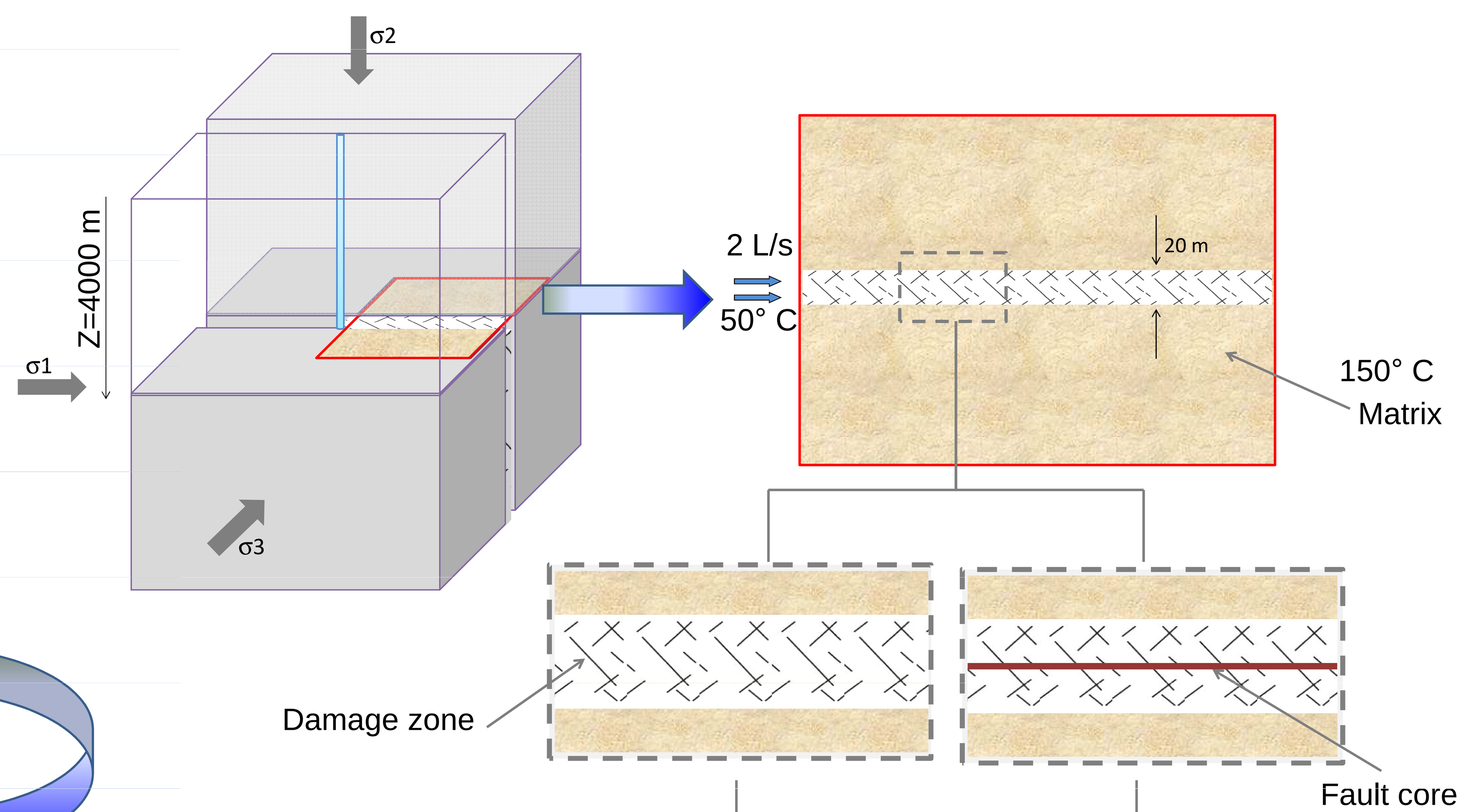
To investigate the potential effects of reservoir heterogeneities, we studied how the fault zone structure can affect the hydro-mechanical and thermo-hydro- mechanical behavior. To fulfill this aim, a simple model of hydraulic stimulation was developed, comparing different fault zone properties and schemes.

3. METHODS

- Several schemes of a vertical fault zone structure embedded in a crystalline matrix;
- Numerical simulation of isothermal (HM) and non-isothermal (THM) water injection;
- 7 days Injection and 7 days shut in;
- Fully coupled simulation with FEM code Code_Bright (Olivella *et al.*, 1996);
- Analysis of the variation of pressure, temperature and stress regime due to the hydraulic and thermal perturbations;
- Analysis of the seismicity tendency in terms of Coulomb Failure Stress variation (ΔCFS), calculated on the favorably oriented plane.

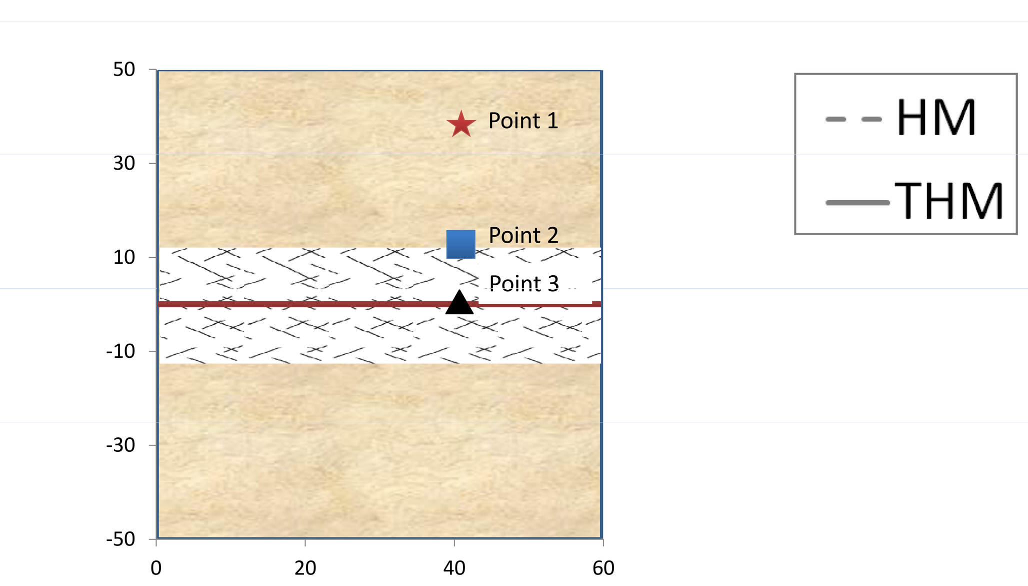
$$CFS = \tau - (c + \mu \cdot \sigma_n')$$

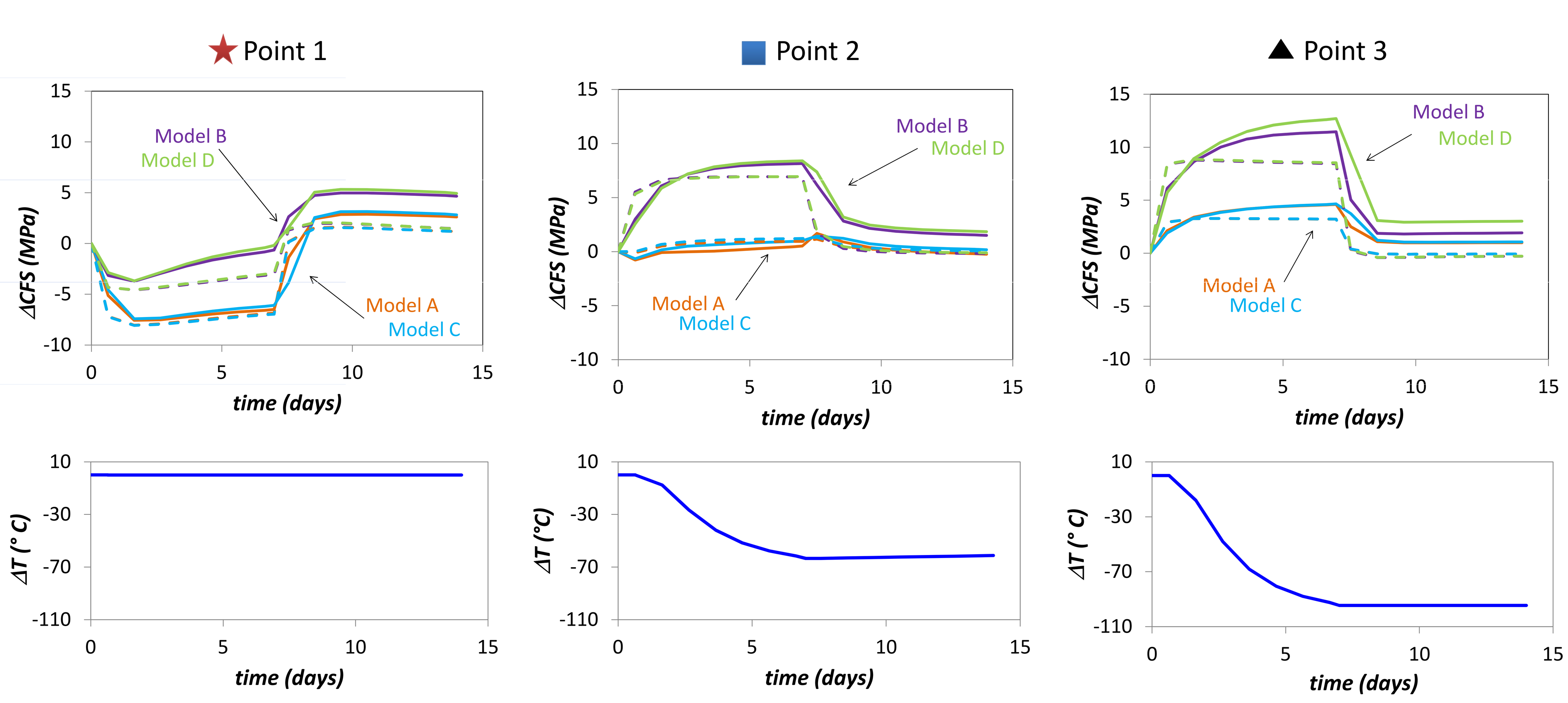
Positive values of *CFS* mean failure; increase of *CFS* (ΔCFS>0) means evolution towards failure condition.



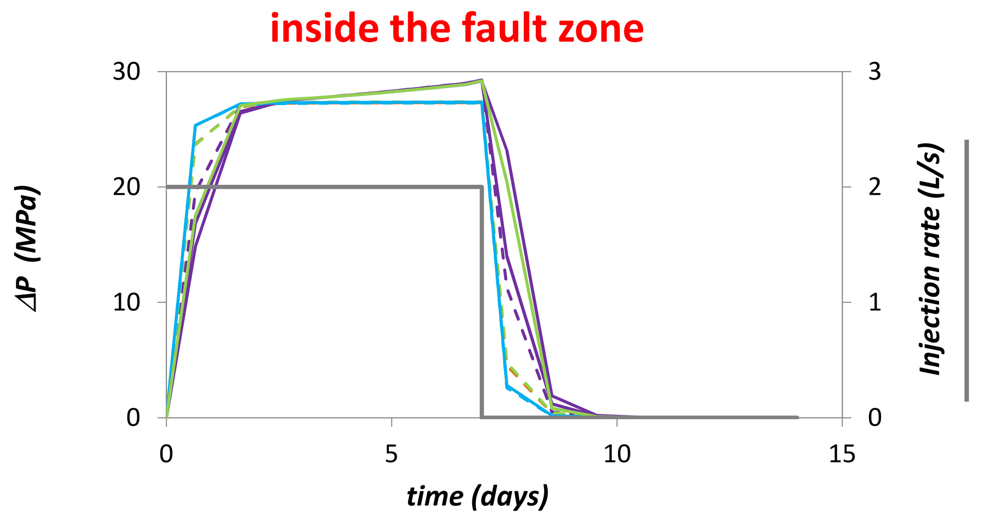
	Model A	Model B	Model C	Model D	
k damage zone	10^{-12}	10^{-12}	10^{-12}	10^{-12}	m^2
E damage zone	1000	5000	1000	5000	MPa
k fault core	-	-	10^{-18}	10^{-18}	m^2
E fault core	-	-	1000	1000	MPa
k matrix	10^{-18}				m^2
E matrix	50000				MPa

4. RESULTS

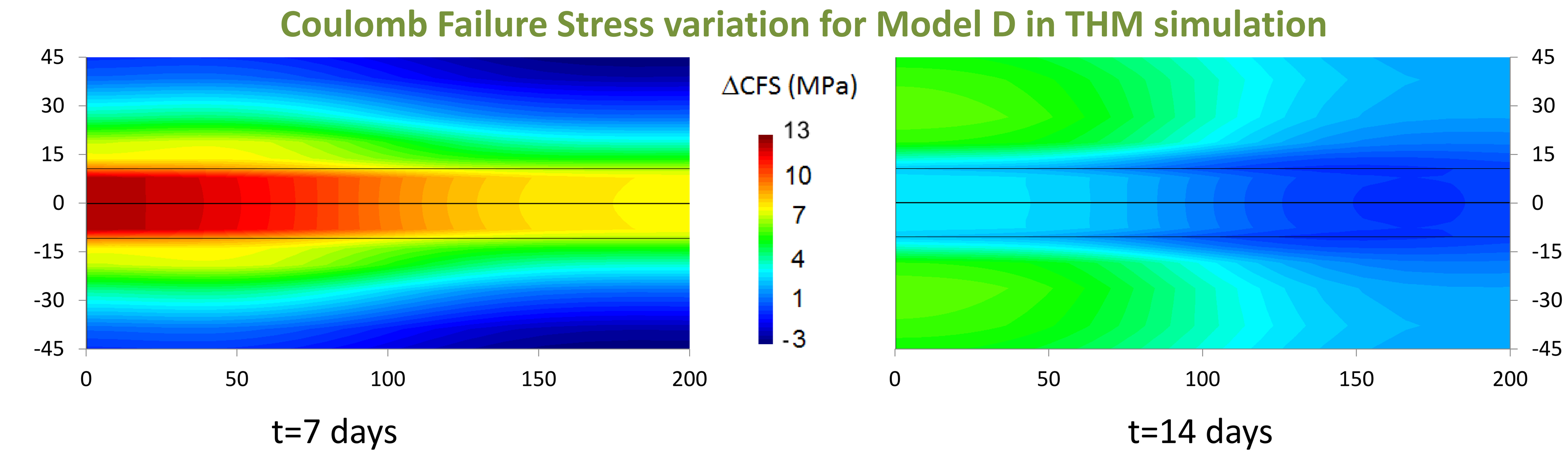




Well injection rate and Pressure Variation inside the fault zone



Coulomb Failure Stress variation for Model D in THM simulation



5. CONCLUSIONS

- Global response is governed by the damage zone behavior, so the inclusion of the fault core appears to be redundant (curves A-C and B-D are almost the same both in HM and THM simulations);
- Stiffness considerably affects the stress state, mostly in the case of non isothermal injection (THM), thus models B and D show greater thermal perturbations;
- During the injection ΔCFS increases inside the fault zone, while post-injection instability is observed in the zone of the matrix near the fault zone.

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