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Evaluating injection strategies for EGS from the temporal evolution of the Gutenberg-Richter b-value.

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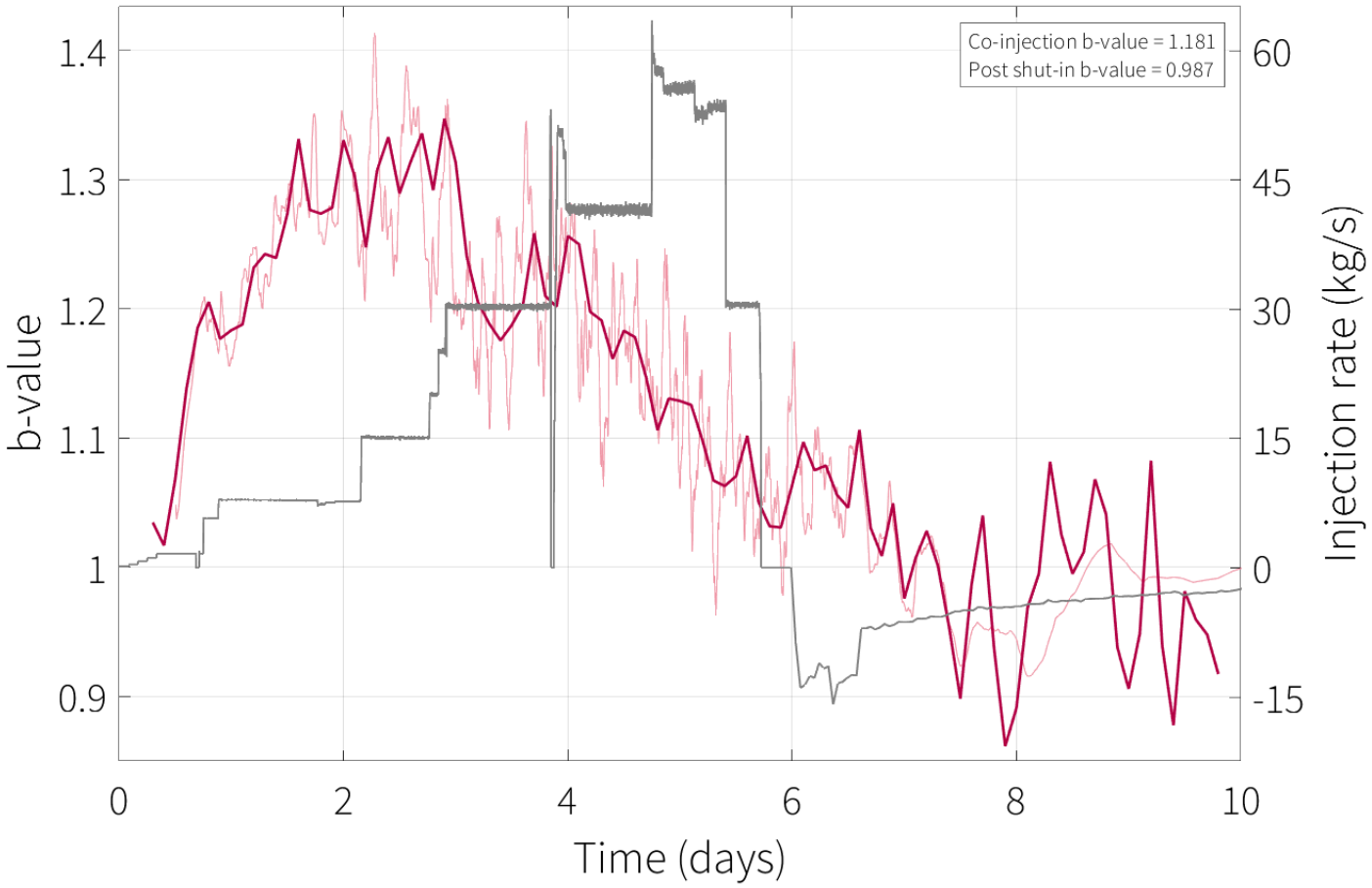
Observed changes in the Gutenberg-Richter b-value

Basel 2006

- The b-value is observed to change in time during stimulation operations
- Modelling with TOUGH2-Seed, a coupled hydro-geomechanical model
- How much is the injection able to influence the b-value?
- Why is the b-value decreasing after 3 days?

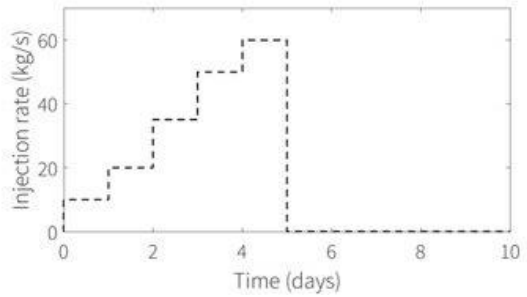


Ritz et al., (in review)
Adapted from Herrmann et al., 2019

What controls the evolution of the b-value in time?

Site conditions

- Step-like injection



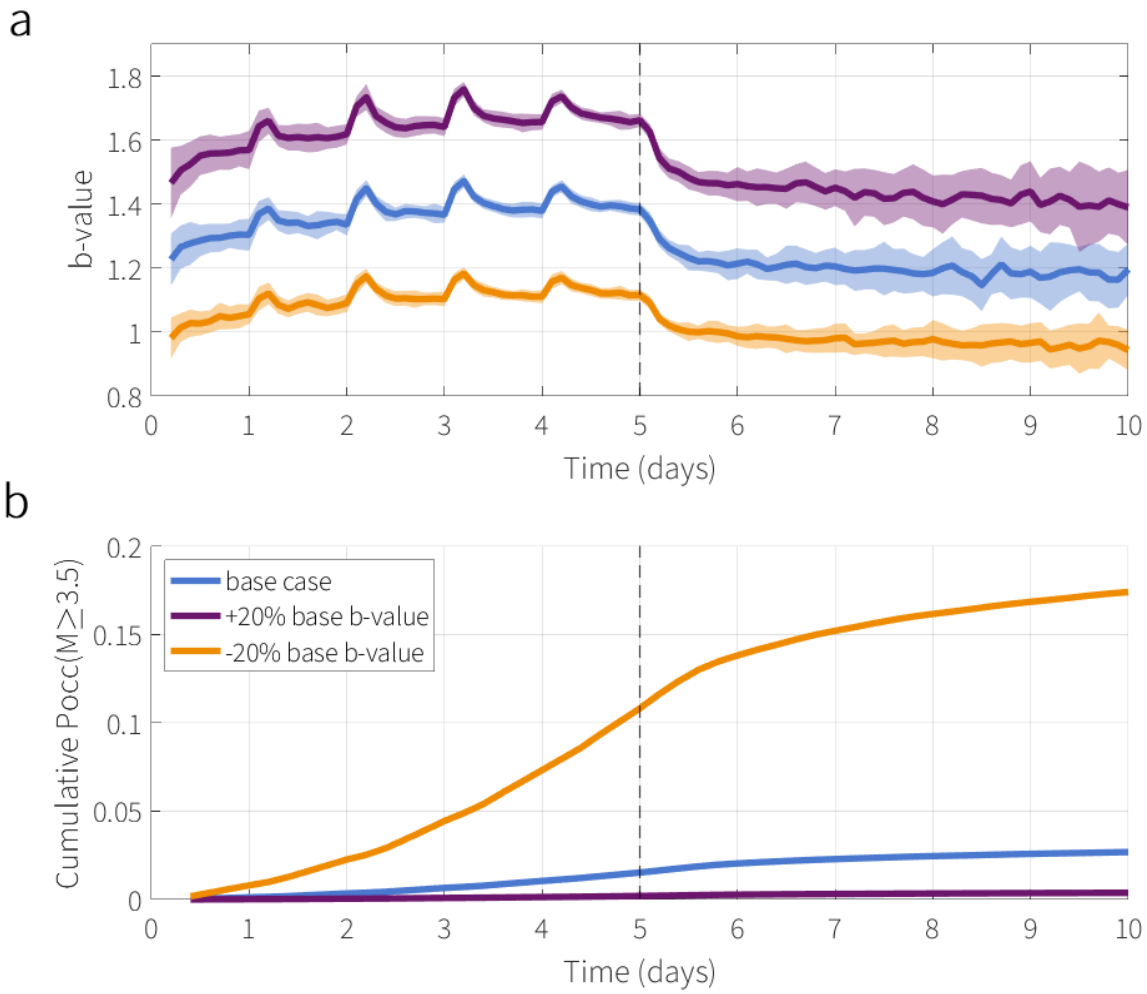
- b-value as a stress meter (*Scholz, 2015* adapted)

$$b = 2.8 - 0.02\sigma_{diff}$$

- Probability of occurrence of an event of magnitude M+ (*Tormann et al., 2014*):

$$T_r(M) = \frac{1}{10^{a-bM}}$$

$$P_{occ}(M) = 1 - e^{\frac{-1}{T_r(M)}}$$

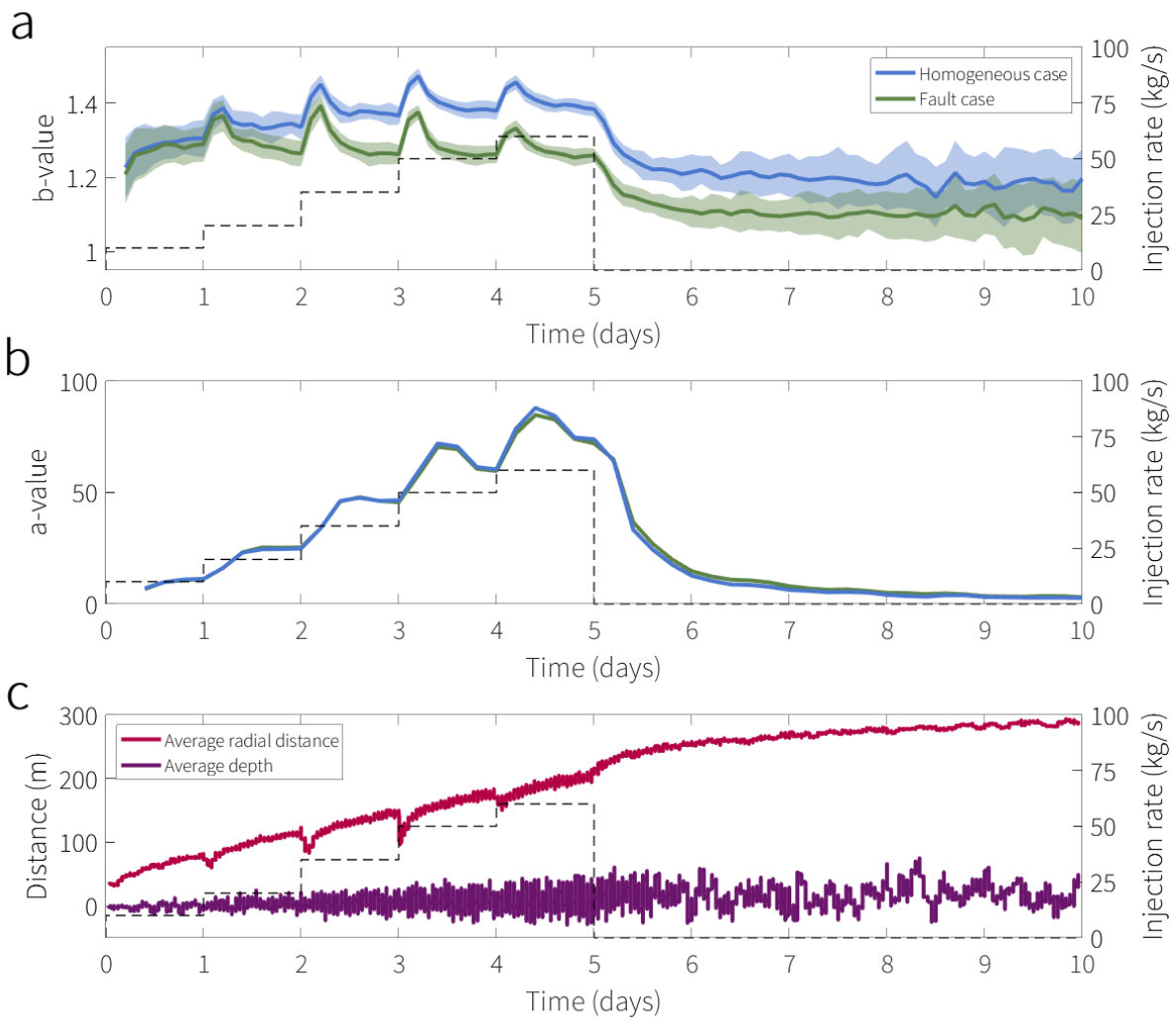


Ritz et al., (in review)

What controls the evolution of the b-value in time?

Presence of a fault

- Higher b-value during injection phase
- Drop of b-value following shut-in
- "Peaks" after injection rate increases driven by repeating events
- With a fault, the b-value starts dropping before shut-in

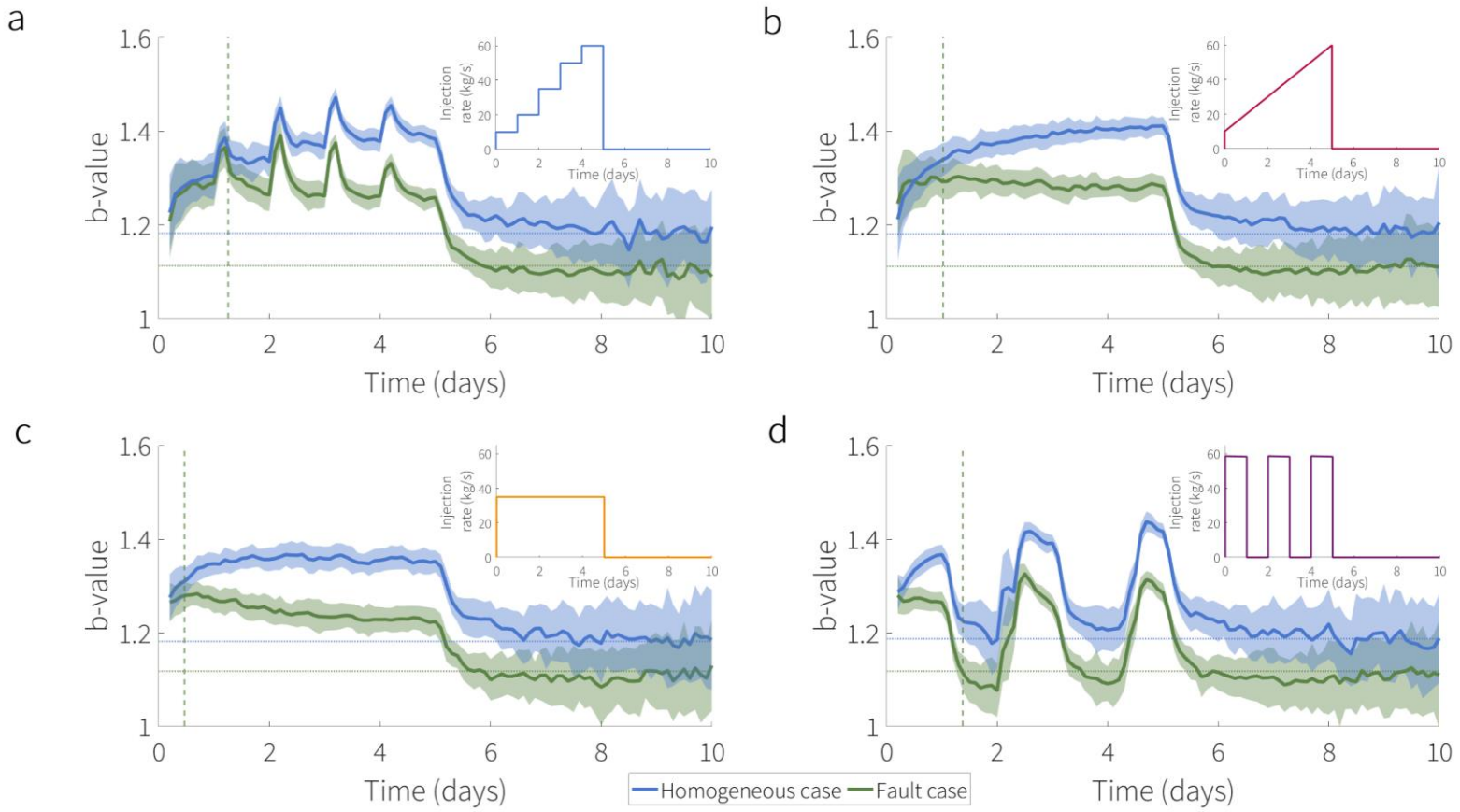


Ritz et al., (in review)

How much is the injection able to influence the b-value?

Evolution of the b-value

- All strategies have the same total injected volume
- The injection pattern changes the b-value evolution
- Cyclic injections give a glimpse of the post shut-in conditions early on

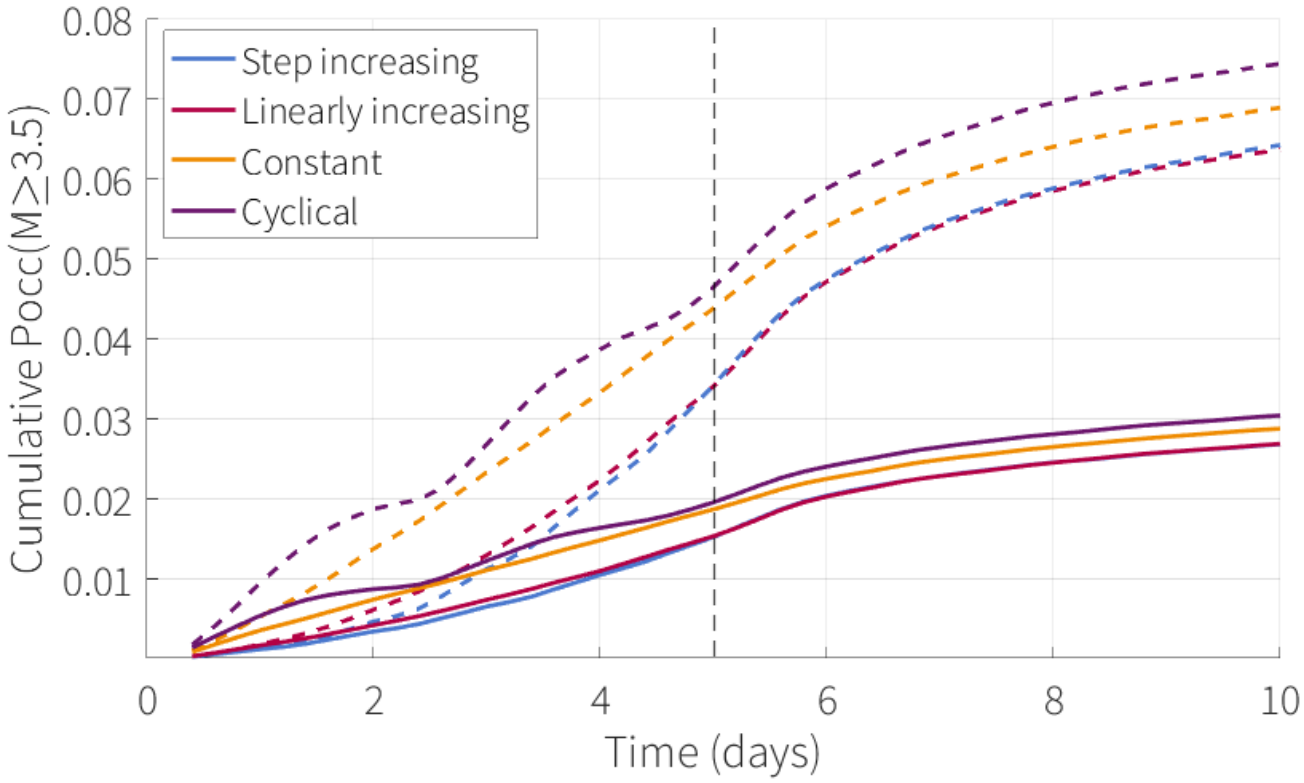


Ritz et al., (in review)

How much is the injection able to influence the b-value?

Associated risk/hazard

- Faults considerably increase the probability of higher magnitudes
- Strategies with monotonously increasing rates are less dangerous than constant and cyclic strategies



Ritz et al., (in review)

Take home message

- Site conditions are the main drivers of risk
- The presence of a fault significantly increases the risk/hazard
- Injection patterns can influence the b-value and the risk/hazard during the injection phase
- Systematic testing with cyclic injections can give a snapshot of b-value, decay rate and other needed parameters to update the risk assessment
- We hope to test these different strategies in the Bedretto lab

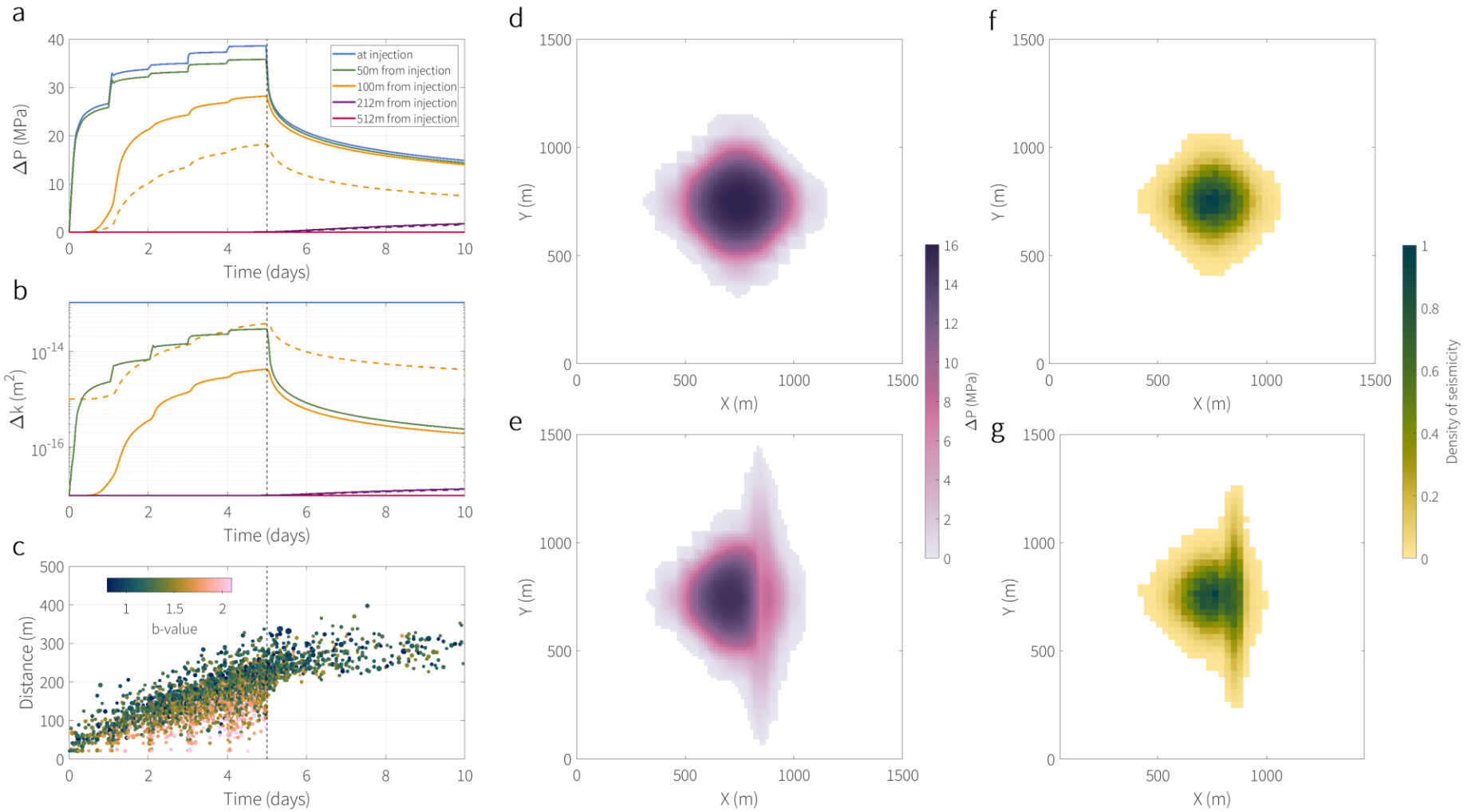
Preprint available!

Read the full story:

Appendix

Modelling results

Step-increasing injection: changes in pressure (a) and permeability (b) during the injection cycle, dashed lines correspond to the case with a fault; (c) R-T plot showing the spatio-temporal distribution of the b-value associated with the reactivated seeds for one realisation; the size of the dots is proportional to the magnitude of the events.
Distribution of the pressure changes after 10 days for the cases without a fault (d) and with a fault (e); density of the seismicity averaged over all realisations without a fault (f) and with a fault (g)



Ritz et al., (in review)