Fluid Initiation of Fracture in Dry and Water Saturated Rocks EGU21-899

Kartseva Tatiana[1,2] (ti.kartceva@physics.msu.ru)

Smirnov Vladimir[1,2], Ponomarev Alexander[2], Patonin Andrey[3],

Isaeva Anna[1], Shikhova Natalia[3], Potanina Maria[1,2], Stroganova Svetlana[2]

[1]*Lomonosov Moscow State University, Faculty of Physics, Moscow, Russia*

[2]*Schmidt Institute of Physics of the Earth, Russian Academy of Science, Moscow, Russia*

[3]*Geophysical Observatory "Borok", Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Borok, Yaroslavskaya oblast, Russia*

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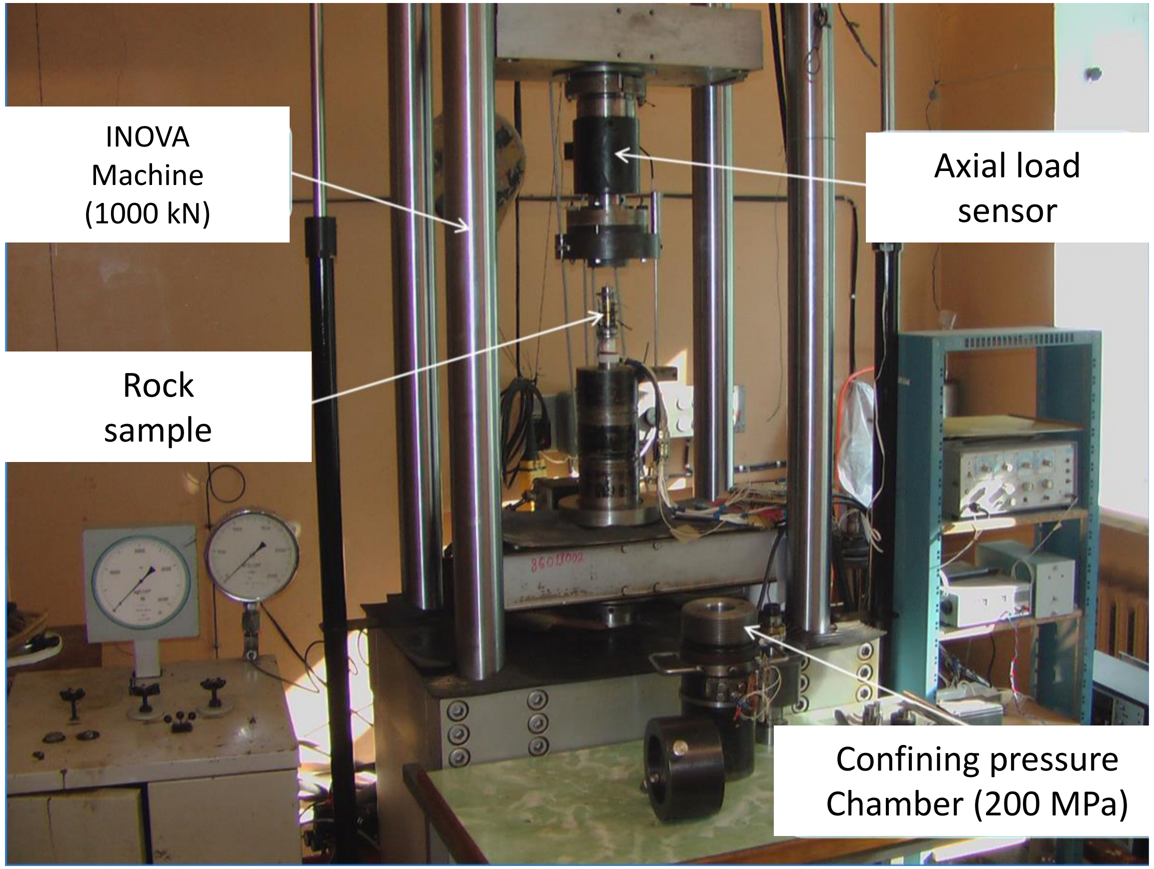
Discussion

1. Laboratory equipment



Electrohydraulic press INOVA-1000 in Geophysical Observatory “Borok”, IPE RAS

- Strain- or Stress-control
- Confining and pore pressure
- Acoustic emission registration system

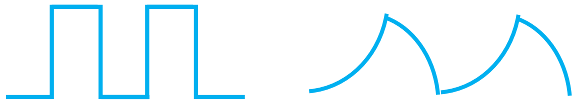
Scheme of experiment

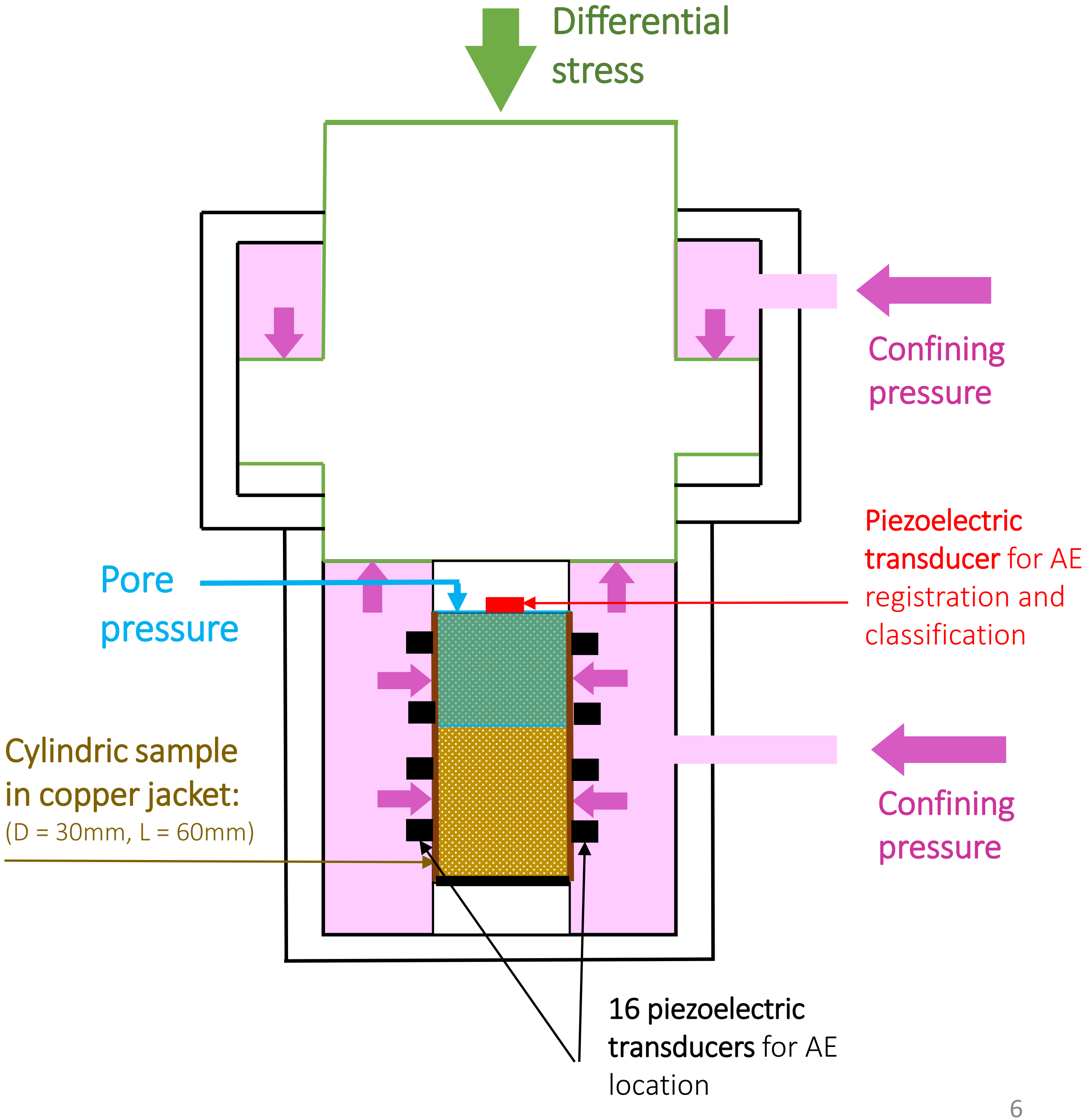
1. A preliminarily dried sample was **initially subjected to uniaxial loading** under confining pressure

2. Loading was performed at a constant strain rate **until the moment of accelerated growth of acoustic emission (AE) rate** (ultimate strength is almost approached)

3. Since that, the **loading rate was decreased** by an order of magnitude, and **water was infused into a sample** from its top face

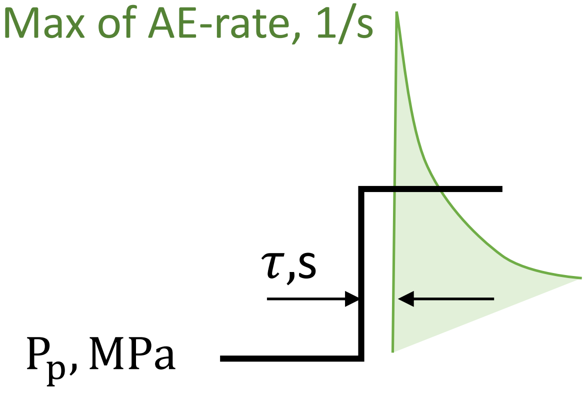
4. After this, the **pore pressure** in the already saturated sample was **raised in sharp and smooth series** of different amplitudes:



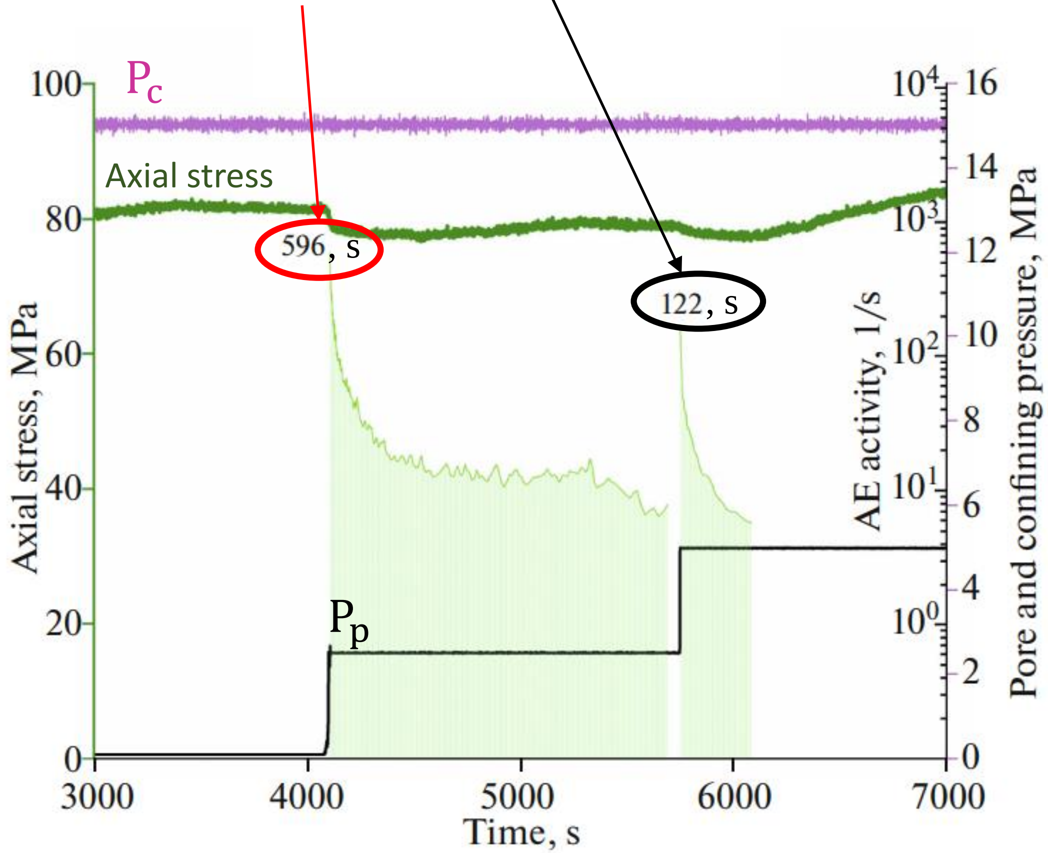


2. Time delay of acoustic response after fluid injection

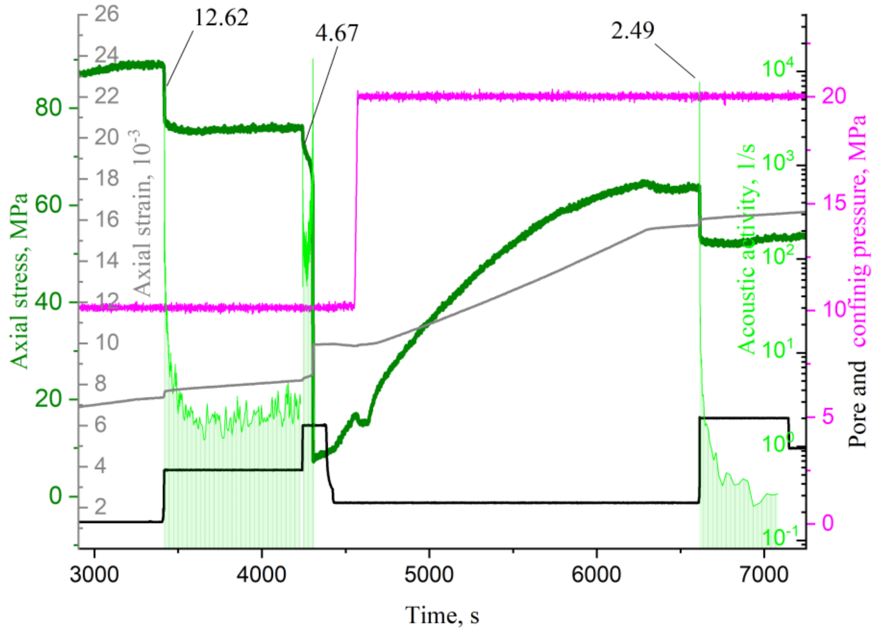
Time delay τ is measured between last moment of pore pressure change and maximum of acoustic emission activity following it

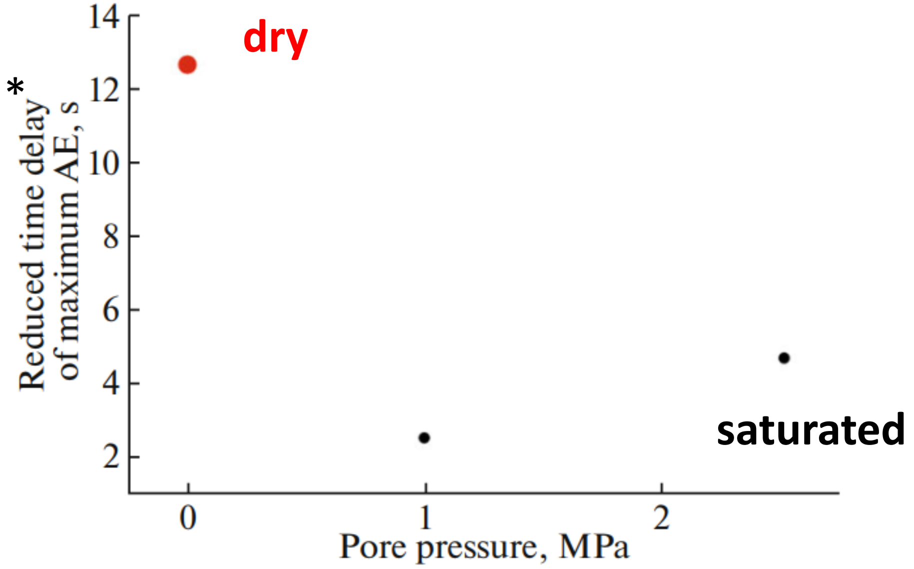


Significant difference between time delays of acoustic response in dry and **saturated** samples

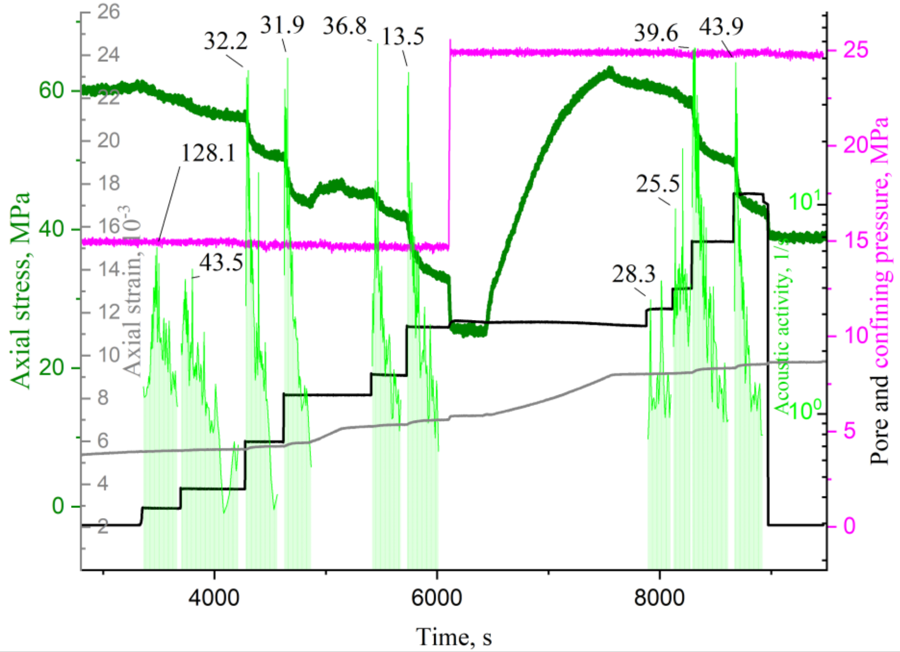


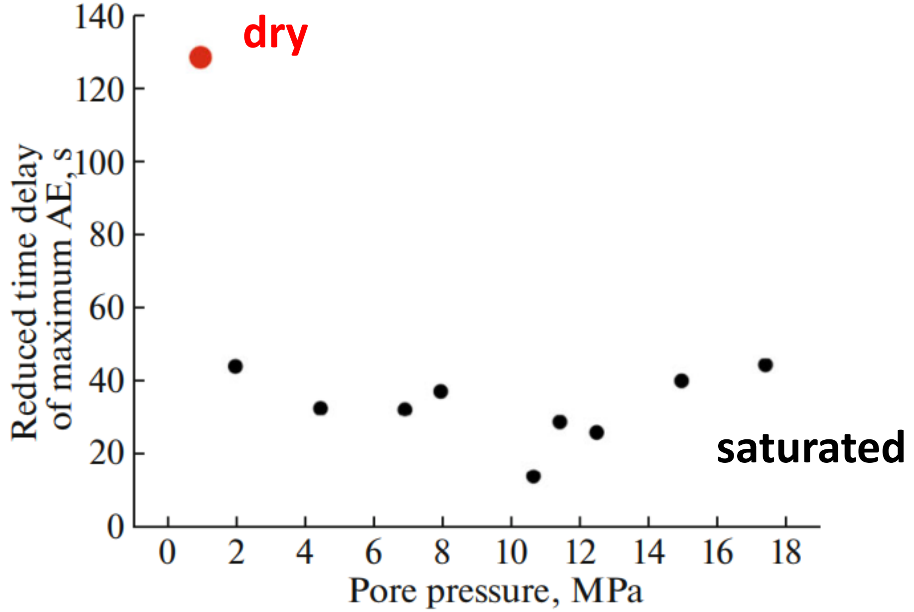
Buffalo sandstone
BuPz-3





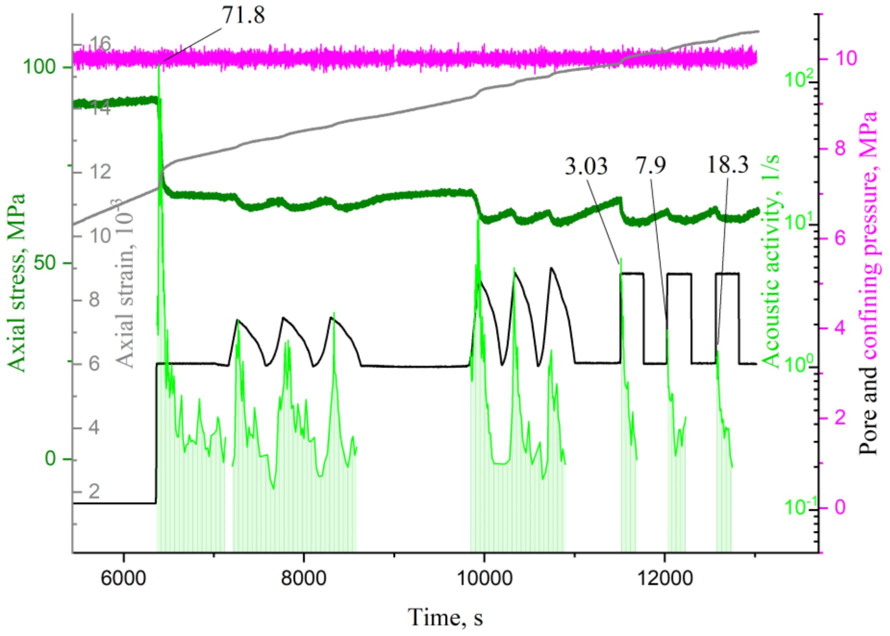
Granite from well in Koyna–Warna region
KBH-5-548-3

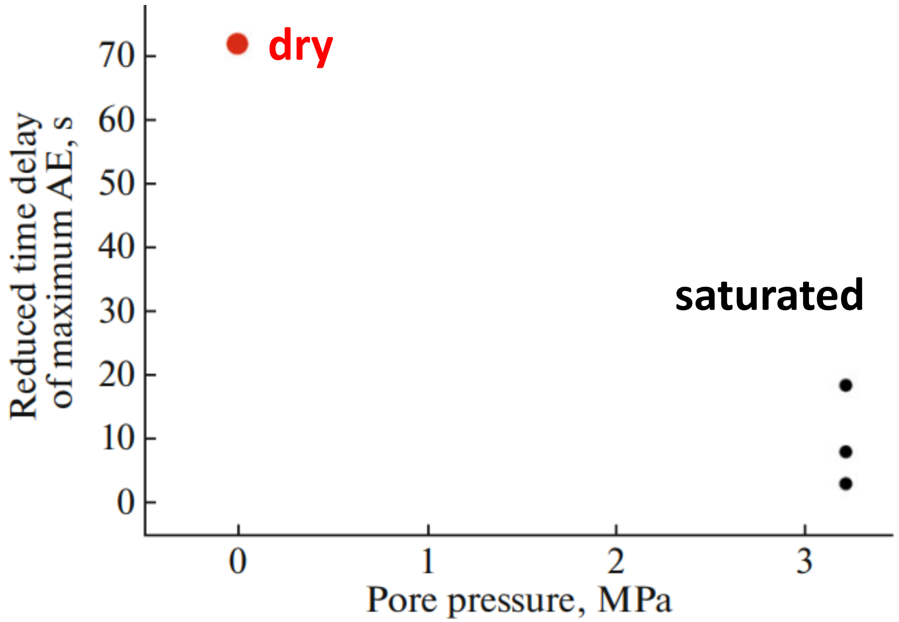




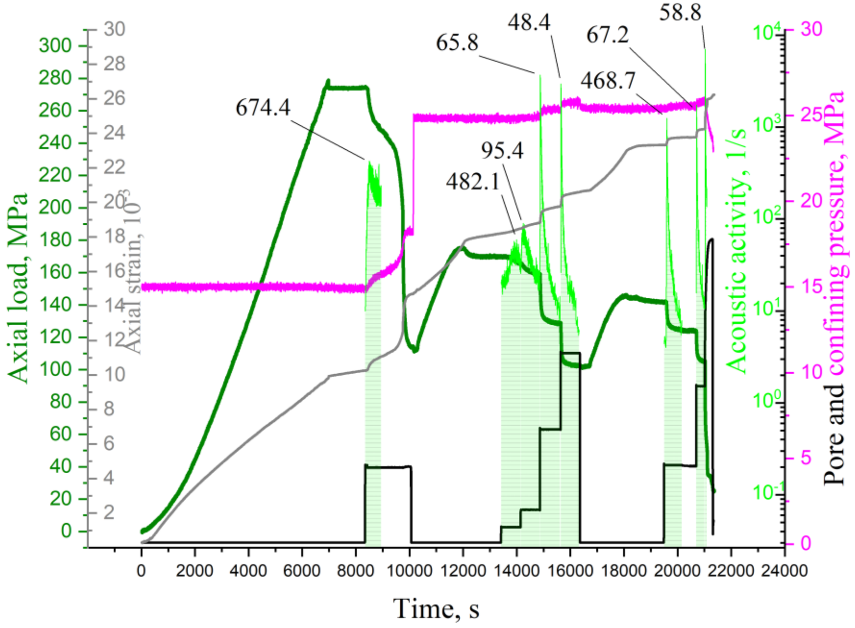
*Reduced time delay: $\tau(1\text{MPa}) = \tau(\Delta P_p)\Delta P_p$

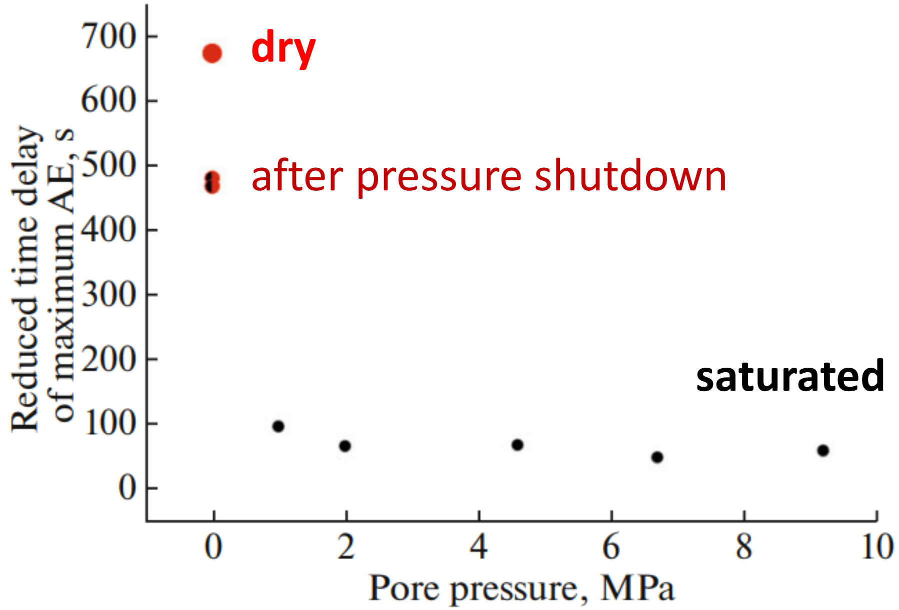
Granite from well in Koyna–Warna region
KBH-5-548-1





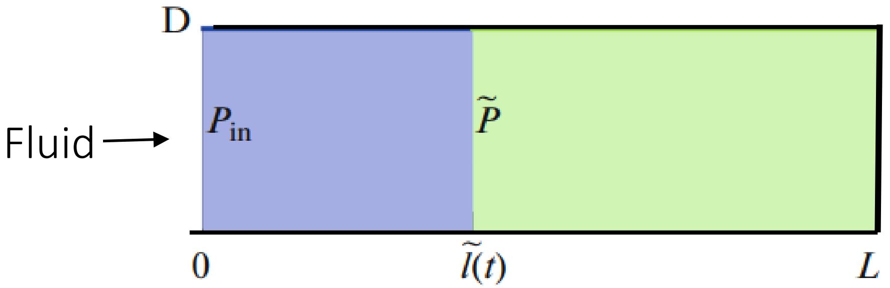
Granite from well in Voronezh crystalline massif
VKM-167-4





3. Numerical simulation of fluid front propagation

$$\varphi \frac{d\tilde{l}}{dt} = \frac{k}{\eta}\left(\frac{P_{in} - P_0\left(1 - \frac{\tilde{l}(t)}{L}\right)^{-1}}{\tilde{l}(t)}\right)$$



φ – porosity
k – absolute permeability
η – dynamic viscosity of a fluid
$\tilde{l}$ – coordinate of the front of air displacement by a fluid
L – sample length (60 mm)
P_{in} – pressure of fluid injection (in experiments is constant)
P_0 - air pressure at the initial moment of time

Rough estimate of the front deceleration time:

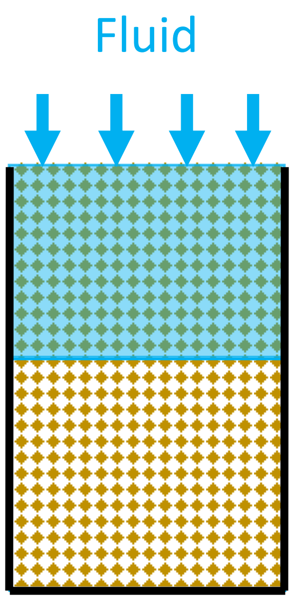
$$t_0 \approx \frac{\varphi \eta L^2}{k P_{in}}$$

Model in details:

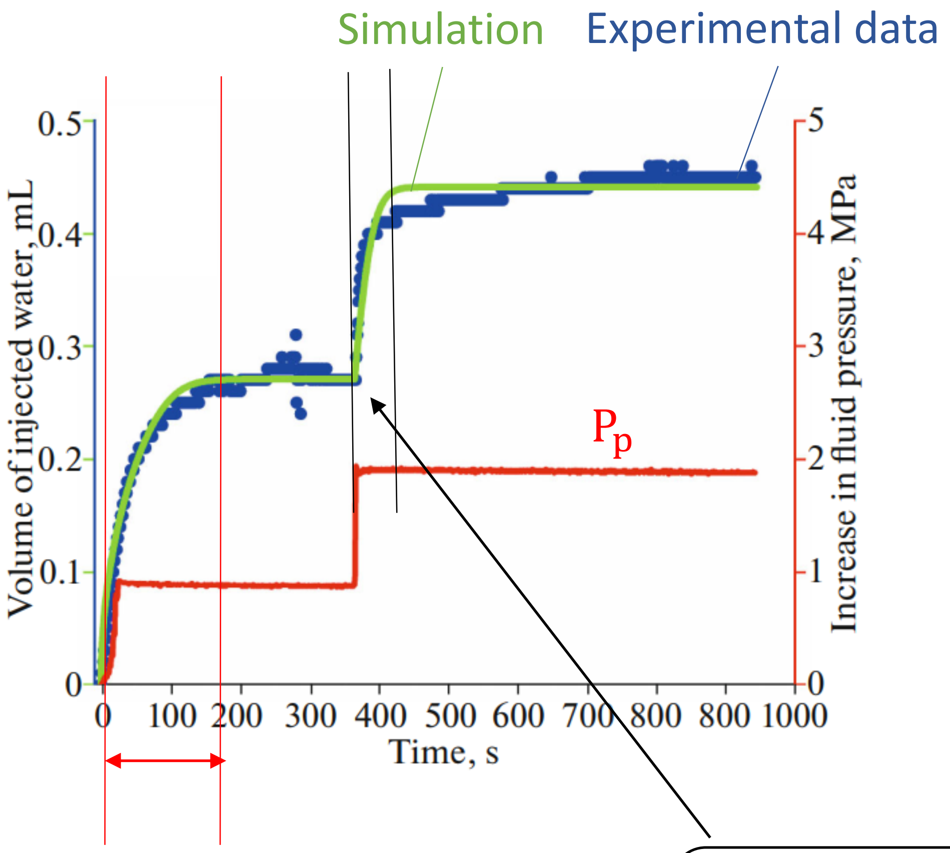
Smirnov, et al (2020). Fluid Initiation of Fracture in Dry and Water Saturated Rocks. Izvestiya, Physics of the Solid Earth

https://link.springer.com/article/10.1134/S1069351320060099

3. Numerical simulation of fluid front propagation



Fluid «piston» displaces air in porous rock



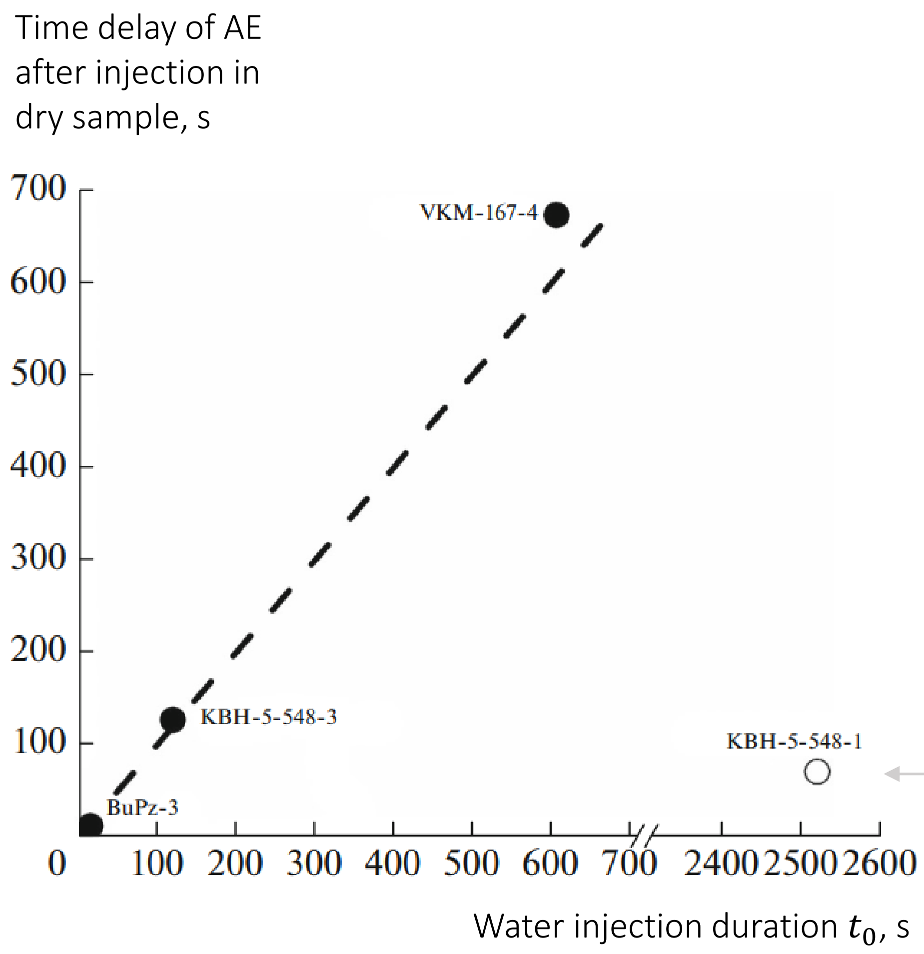
Sample KBH-5-548-3

Injection in **dry** sample, compression of air, <u>propagation of water front</u>

Injection in **saturated** sample reaches constant rate faster – <u>propagation of Pp front</u>

3. Numerical simulation of fluid front propagation

Acoustic response and fluid motion kinematics



It can be seen that in three of the four samples, the time delay of the AE response approximately coincides with the characteristic time of filling a sample with water. This means that the **time delay of the AE response is mainly determined by the propagation time of the water front**.

Probable triggering effect of AE activation

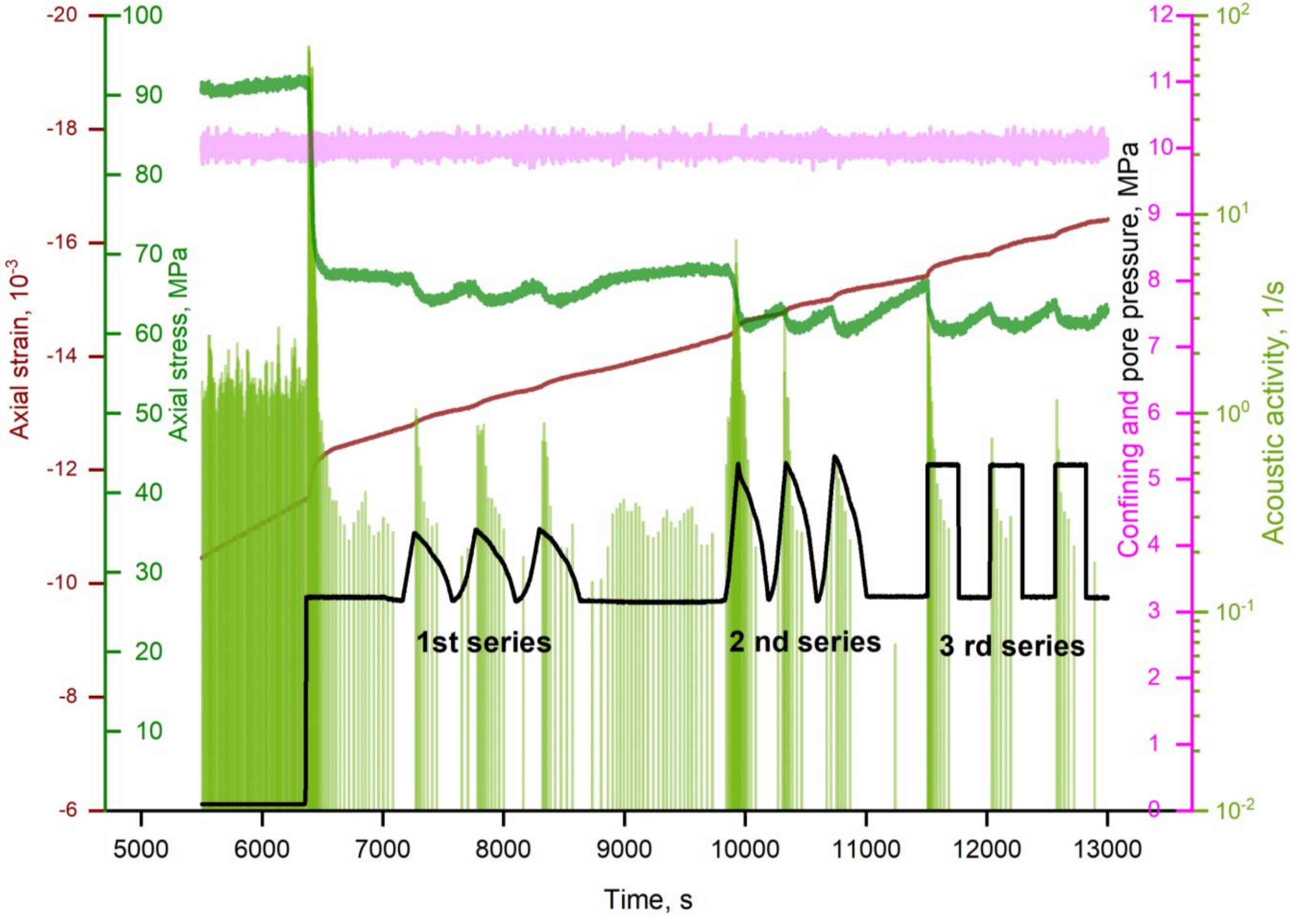
4. Variations of Gutenberg-Richter b-value during fluid injection in granite from Koyna-Warna region

KBH-5-548-1

Granite sample was taken at a depth of 548m from a well in the Koyna Warna RTS region, Western India

Periodical rises and following drops of pore pressure could be similar to seasonal variation of the pore pressure in the crust in area of Koyna and Warna reservoirs.

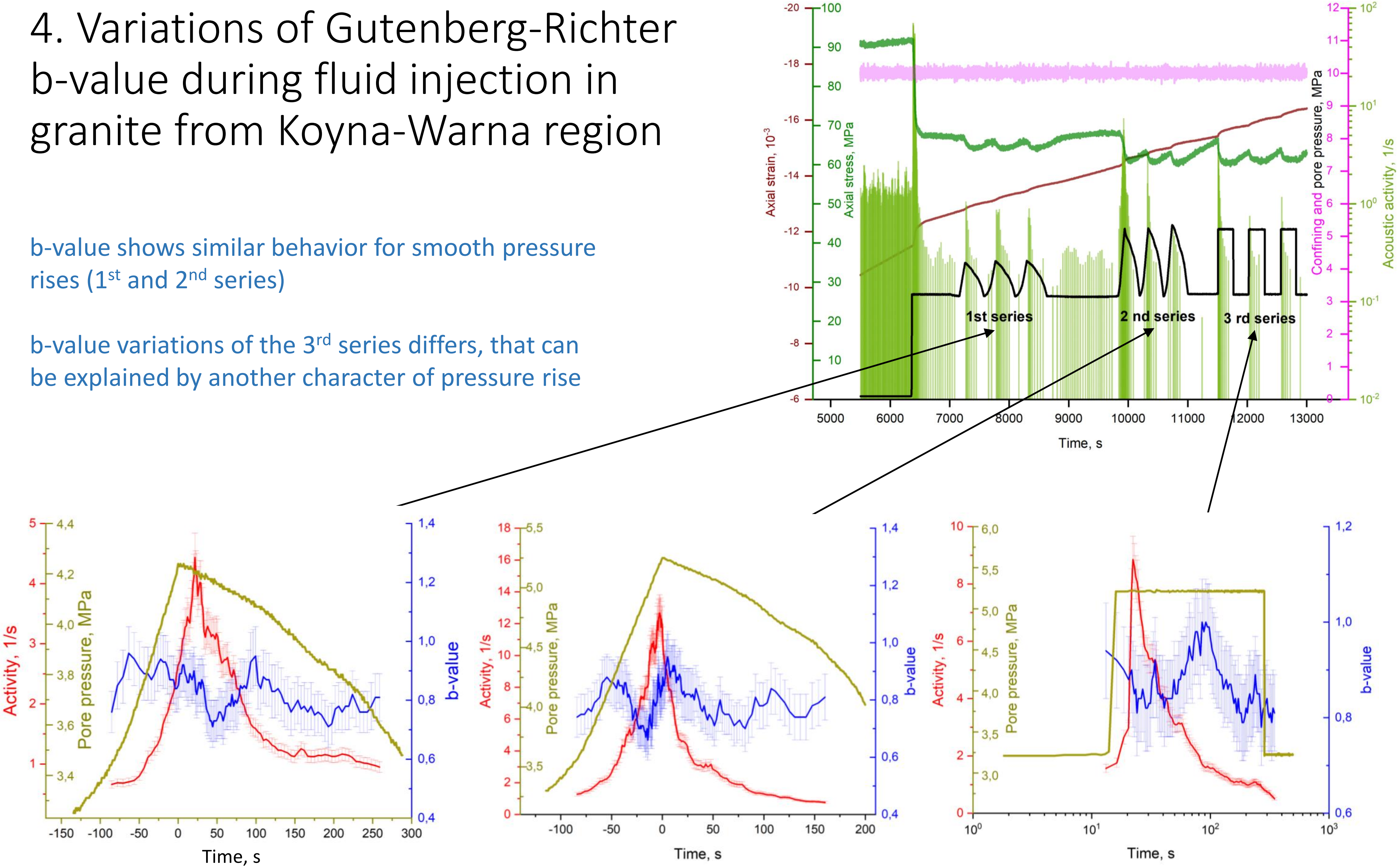
For better statistics of AE-events we stacked catalogues of all rises inside each of three series of pressure change. The reference time moment for each mini-catalogue is a moment of pore pressure peak.



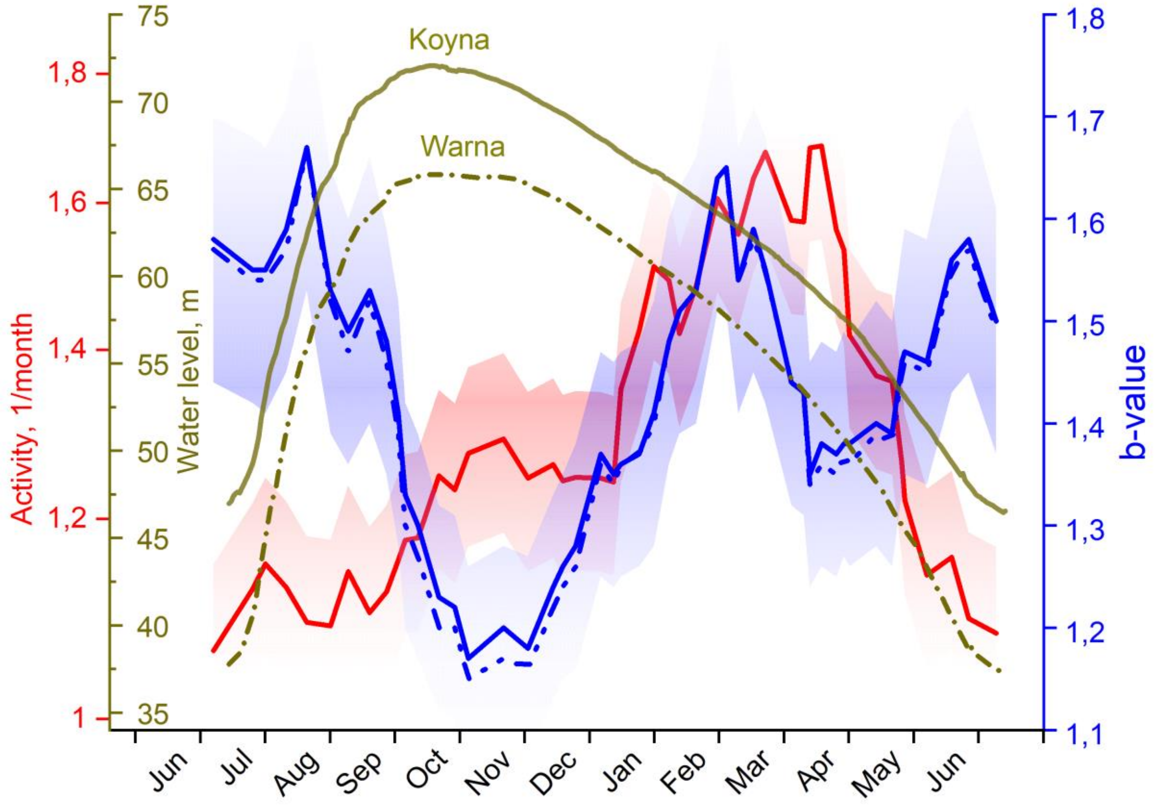
4. Variations of Gutenberg-Richter b-value during fluid injection in granite from Koyna-Warna region

b-value shows similar behavior for smooth pressure rises (1st and 2nd series)

b-value variations of the 3rd series differs, that can be explained by another character of pressure rise



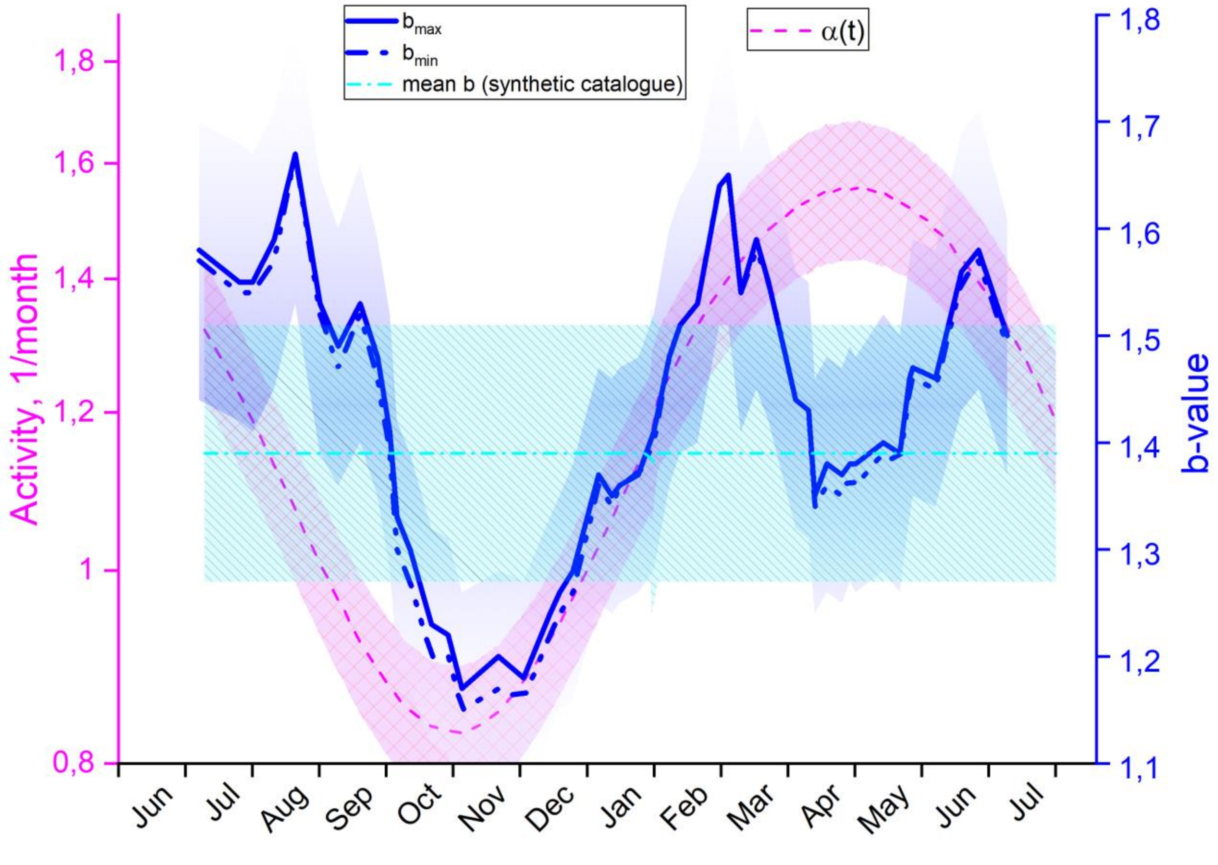
5. Seasonal variations of Gutenberg-Richter b-value and seismic activity in Koyna-Warna region



Initial seismic catalogue MERI (state of Maharashta) 1983-2015 years

- All year-catalogues were stacked to achieve better statistics
- 1999, 2000, 2005 years were excluded because of mainshock-aftershock activity
- The volume of whole catalogue with magnitudes M3+ decreased to **512 events** (43 event per month)
- b-value and seismic activity were estimated in sliding windows
- b-value was estimated by maximum likelihood estimator [Aki, 1985]

5. Seasonal variations of Gutenberg-Richter b-value and seismic activity in Koyna-Warna region



10000 synthetic catalogues with periodical activity were generated to verify independence of b-value changes on activity changes:

- Volume of each catalogue is 512 events
- Magnitude distribution $P(M) = \lambda e^{-\lambda M}$

$$\lambda = b\,ln10,\ b = 1.4$$

- Time between successive events $P(\tau) = \alpha e^{-\alpha\tau}$
- Activity: $\alpha(t) = \alpha_0\left(1 + \beta\cos\left(\frac{2\pi}{T}t\right)\right)$

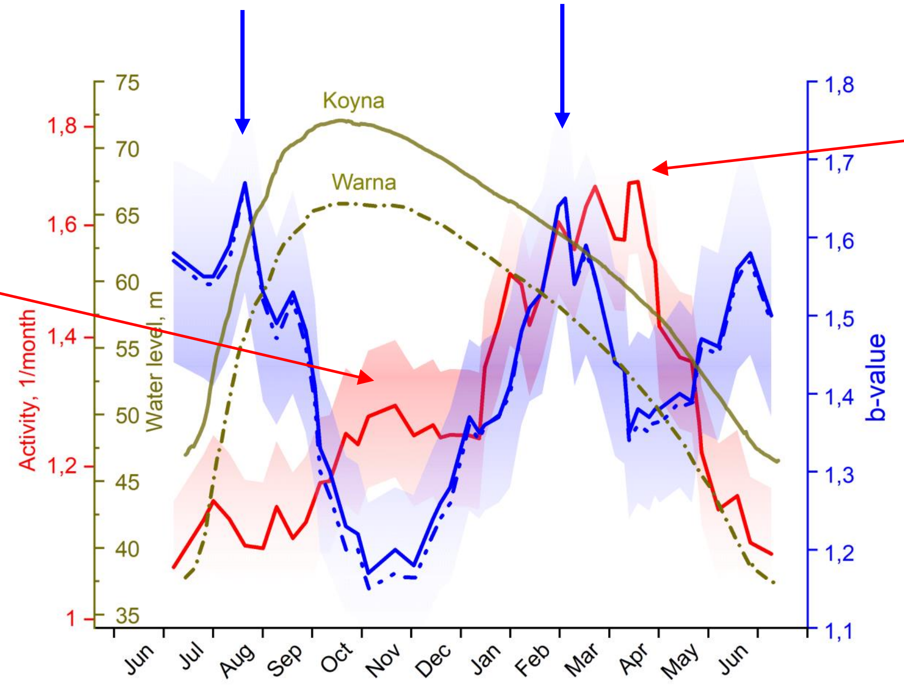
α_0 – mean activity of real catalogue

$\beta = \frac{A_{max} - A_{min}}{2}$ – a half of activity range

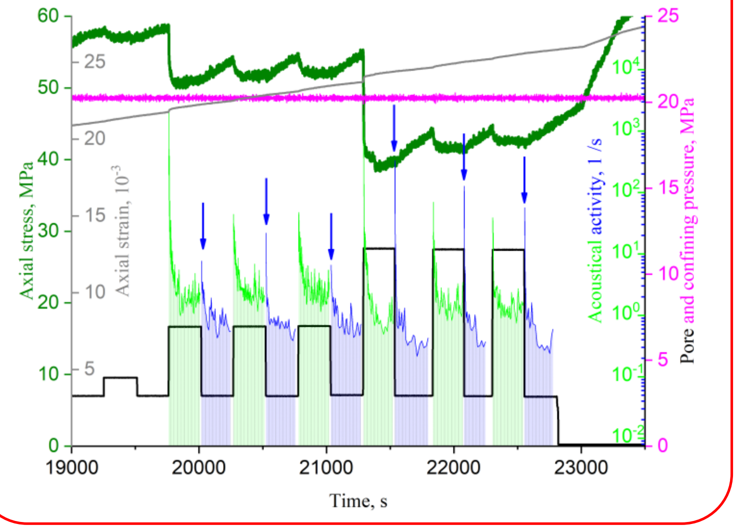
Filled patterns show 1 standard deviations. We see that b-value of synthetic catalogues doesn't have any variations in spite of activity variations. Also, variations of b-value of real catalogue is larger than 1 standard deviation of b-value of random catalogues.

Discussion

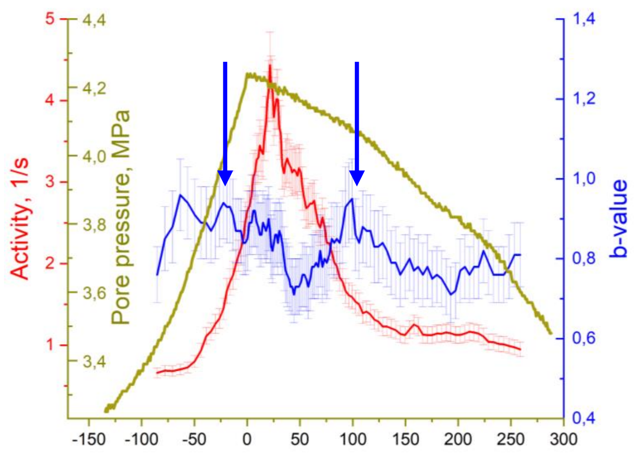
Instantaneous response:
instantaneous loading on reservoir bottom

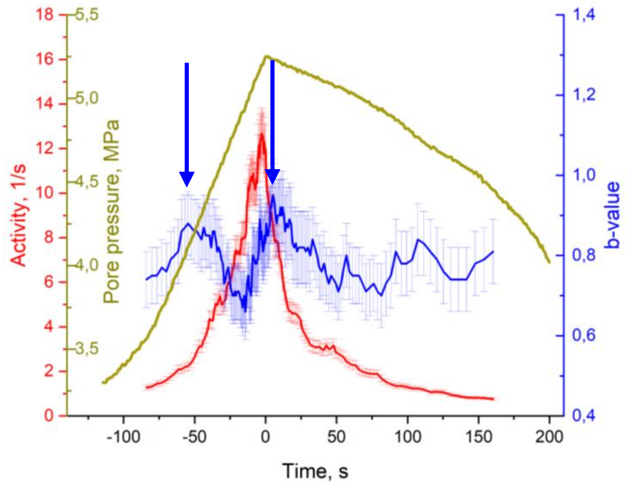


Delayed response:
diffusion of fluid in the crust?
or
response on pore pressure drop?



2 peaks of b-value probably conditioned by rise and drop of pressure rather than by maximum of acoustical (or seismic) response





Open question

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Acknowledgements

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Related articles

Smirnov, V. B., Ponomarev, A. V., Isaeva, A. V., Bondarenko, N. B., Patonin, A. V., Kaznacheev, P. A., ... & Arora, K. (2020). **Fluid Initiation of Fracture in Dry and Water Saturated Rocks**. Izvestiya, Physics of the Solid Earth, 56(6), 808-826. https://link.springer.com/article/10.1134/S1069351320060099

Smirnov, V. B., Mikhailov, V. O., Ponomarev, A. V., Arora, K., Chadha, R. K., Srinagesh, D., & Potanina, M. G. (2018). **On the dynamics of the seasonal components of induced seismicity in the Koyna–Warna region, Western India**. Izvestiya, Physics of the Solid Earth, 54(4), 632-640.https://link.springer.com/article/10.1134/S1069351318040109

Thank you for attention!

Questions?