# FLUID-DRIVEN EARTHQUAKE SEQUENCES AND ASEISMIC SLIP

## IN A PORO-VISCO-ELASTO-PLASTIC FLUID-BEARING FAULT STRUCTURE

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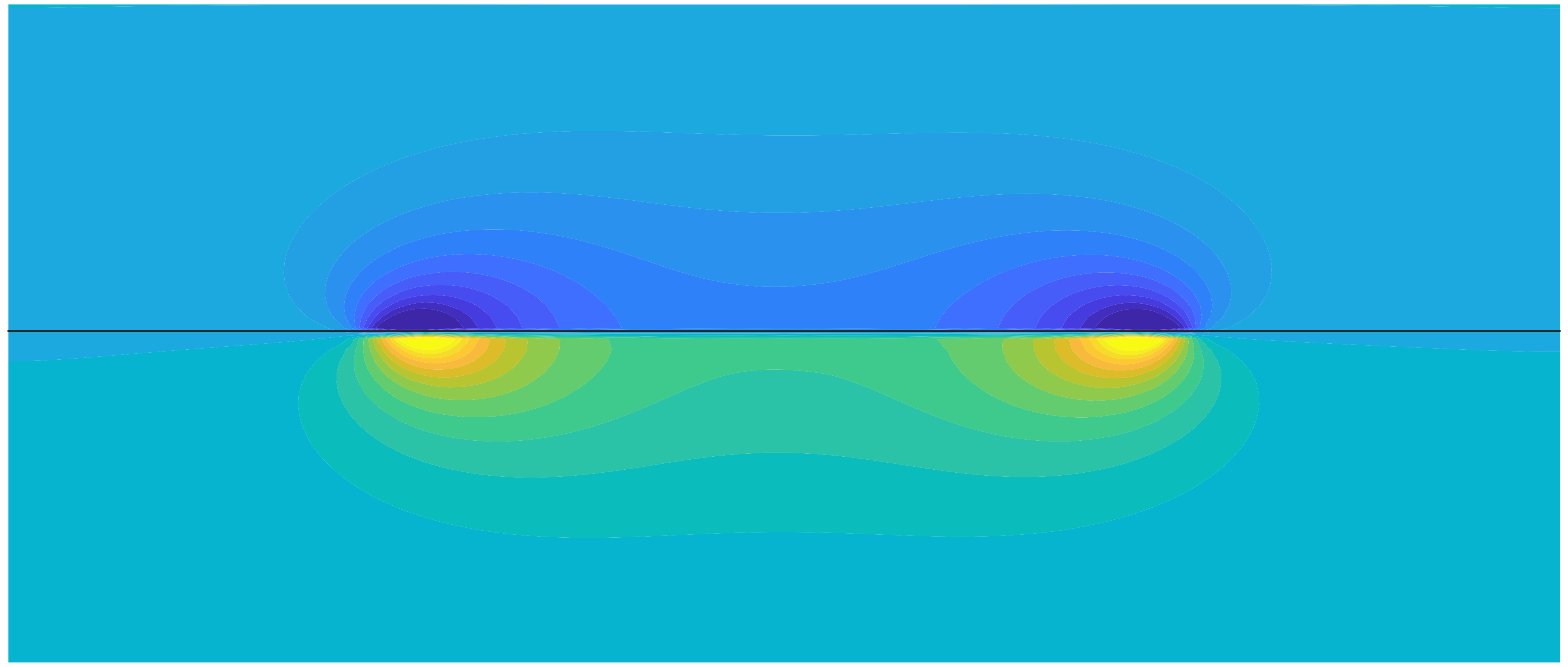

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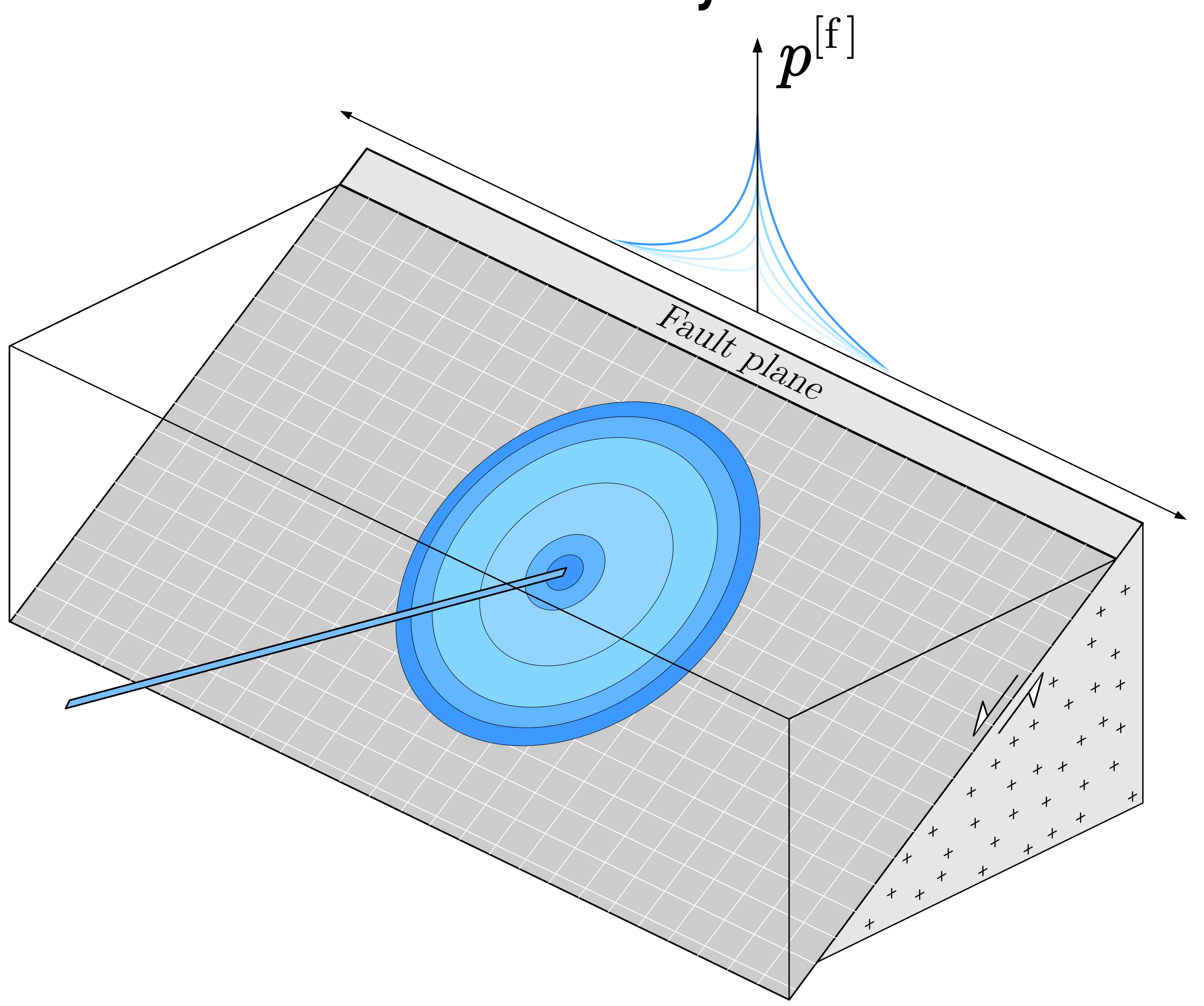
ETH zürich    Bedretto Lab    erc European Research Council Established by the European Commission    FEAR Fault Activation and Earthquake Rupture

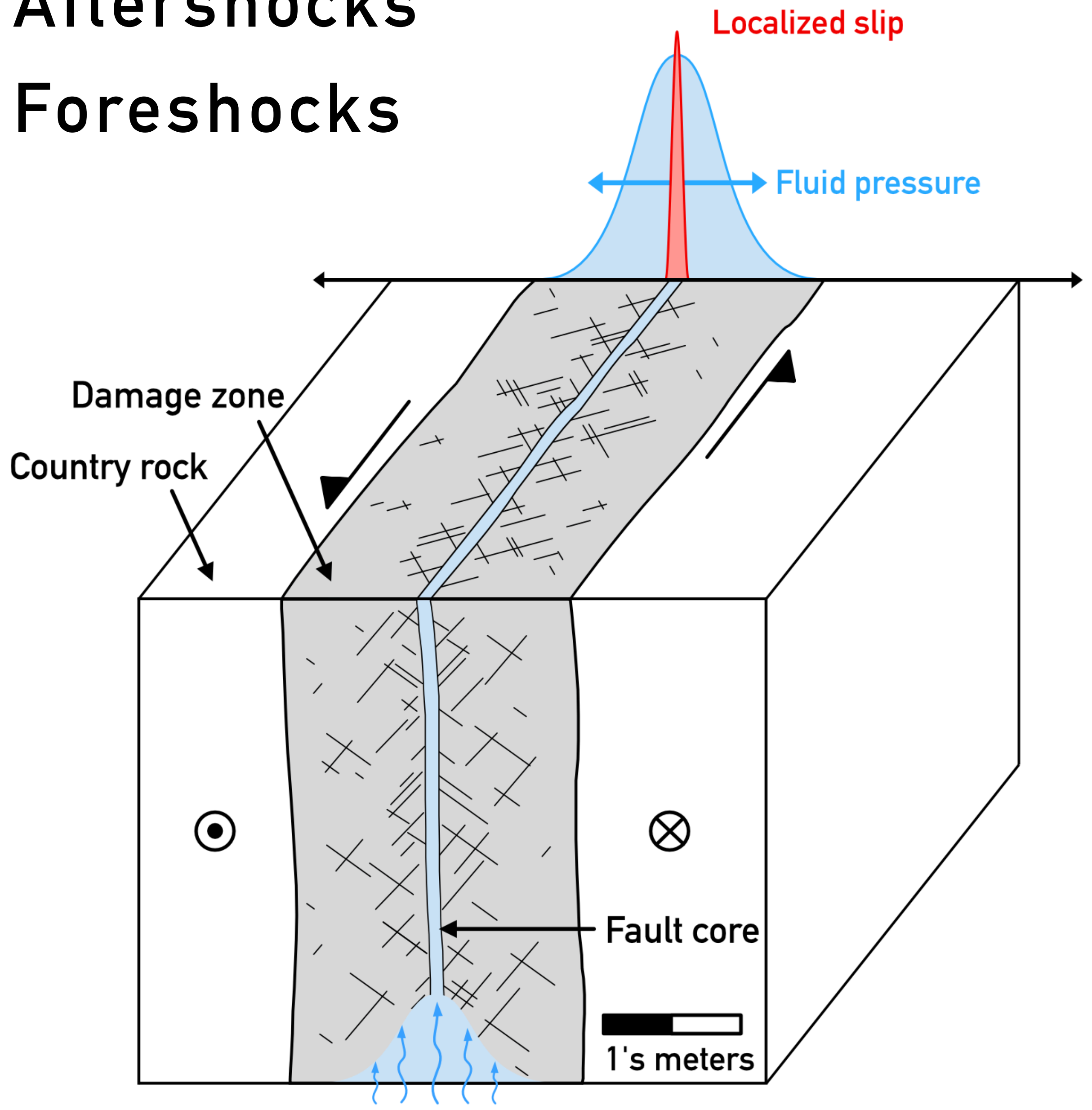
# The role of fluids in tectonic and earthquake processes

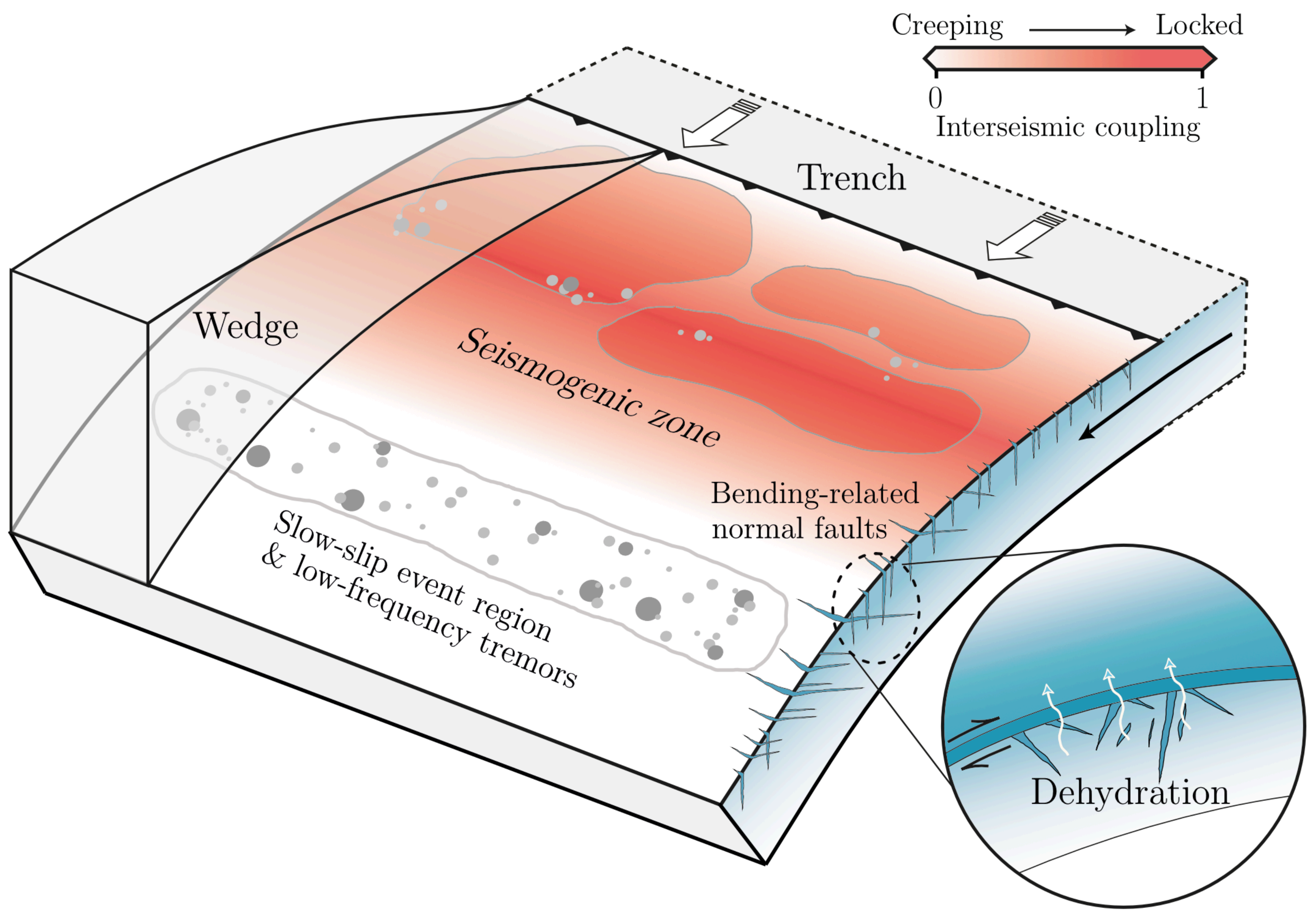
Spatial scales

- Fluid injection
- Induced seismicity




- Swarms
- Aftershocks
- Foreshocks




- Long-term dehydration
- Slow-slip events and tremors
- Large megathrust earthquakes

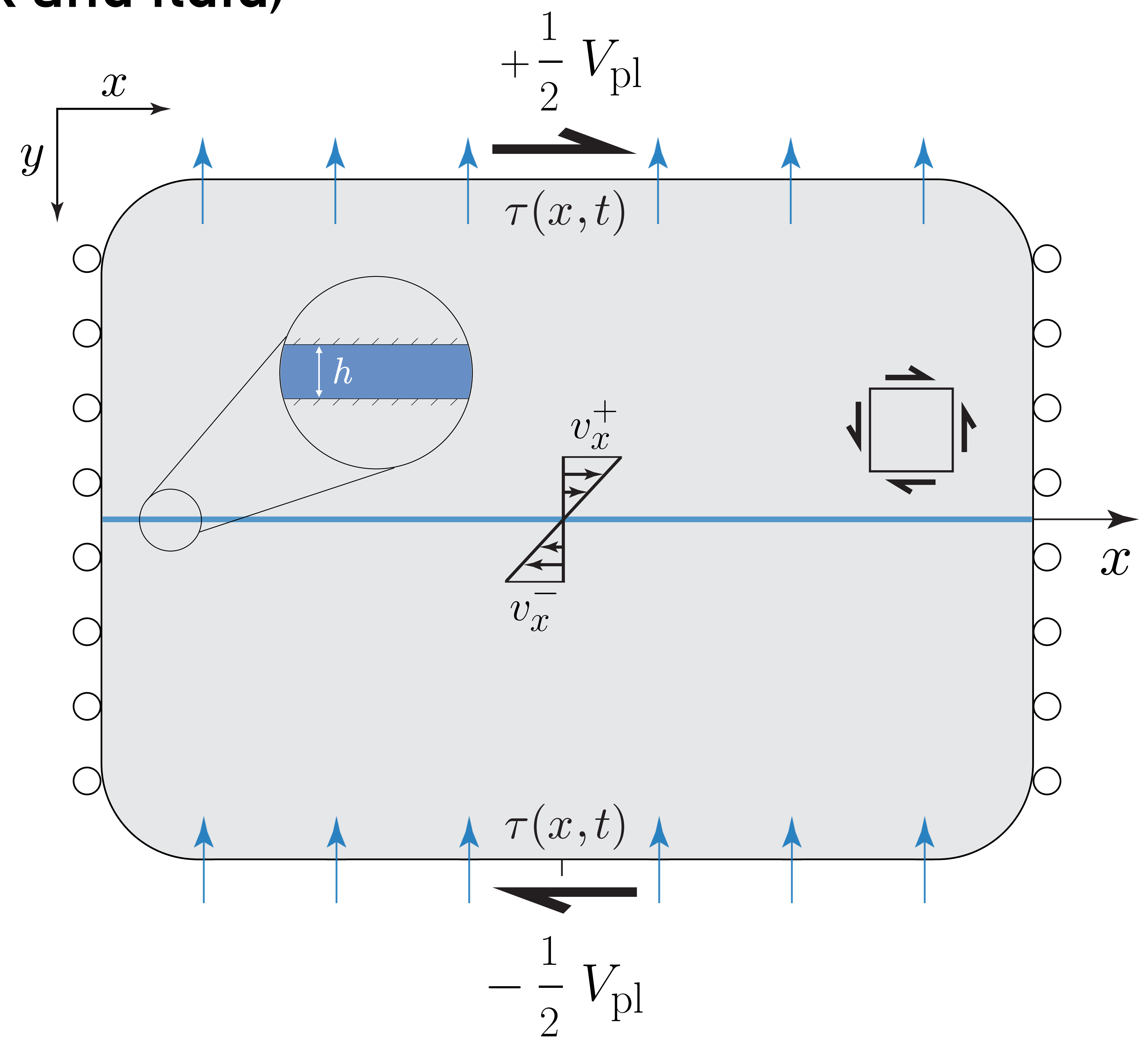
There is a growing interest in understanding how geologic faults respond to transient source of fluids…

Temporal scales

# H-MECs: Hydro-Mechanical Earthquake Cycles

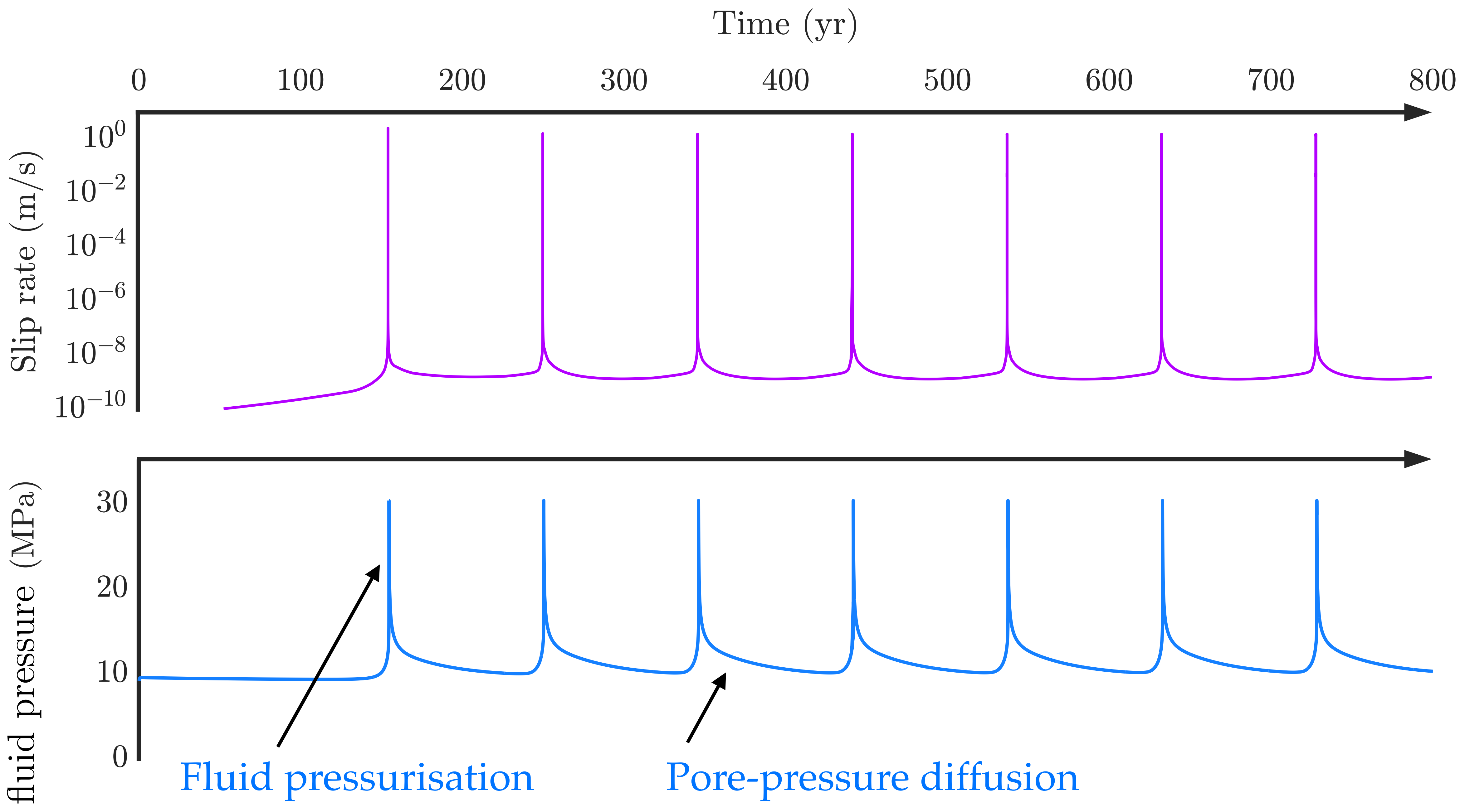
- Conservation equations for total momentum (solid matrix and fluid)
- Fluid momentum
- Fully compressible solid mass
- Fully compressible fluid mass

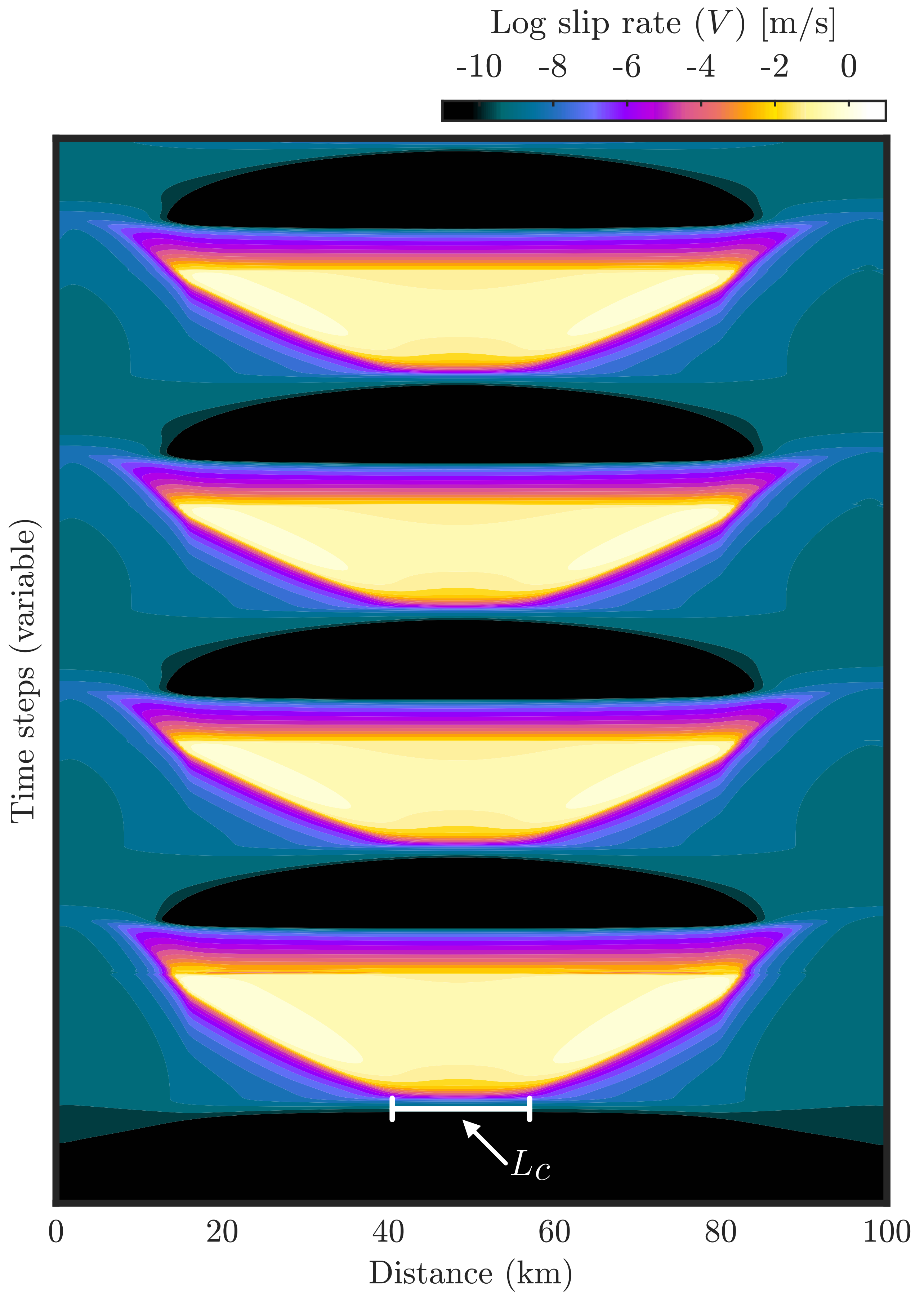
**+** Inertia (fully dynamic)
**+** Visco-elasto-plastic rheology
**+** Adaptive time stepping
**+** Plasticity model: rate-dependent strength

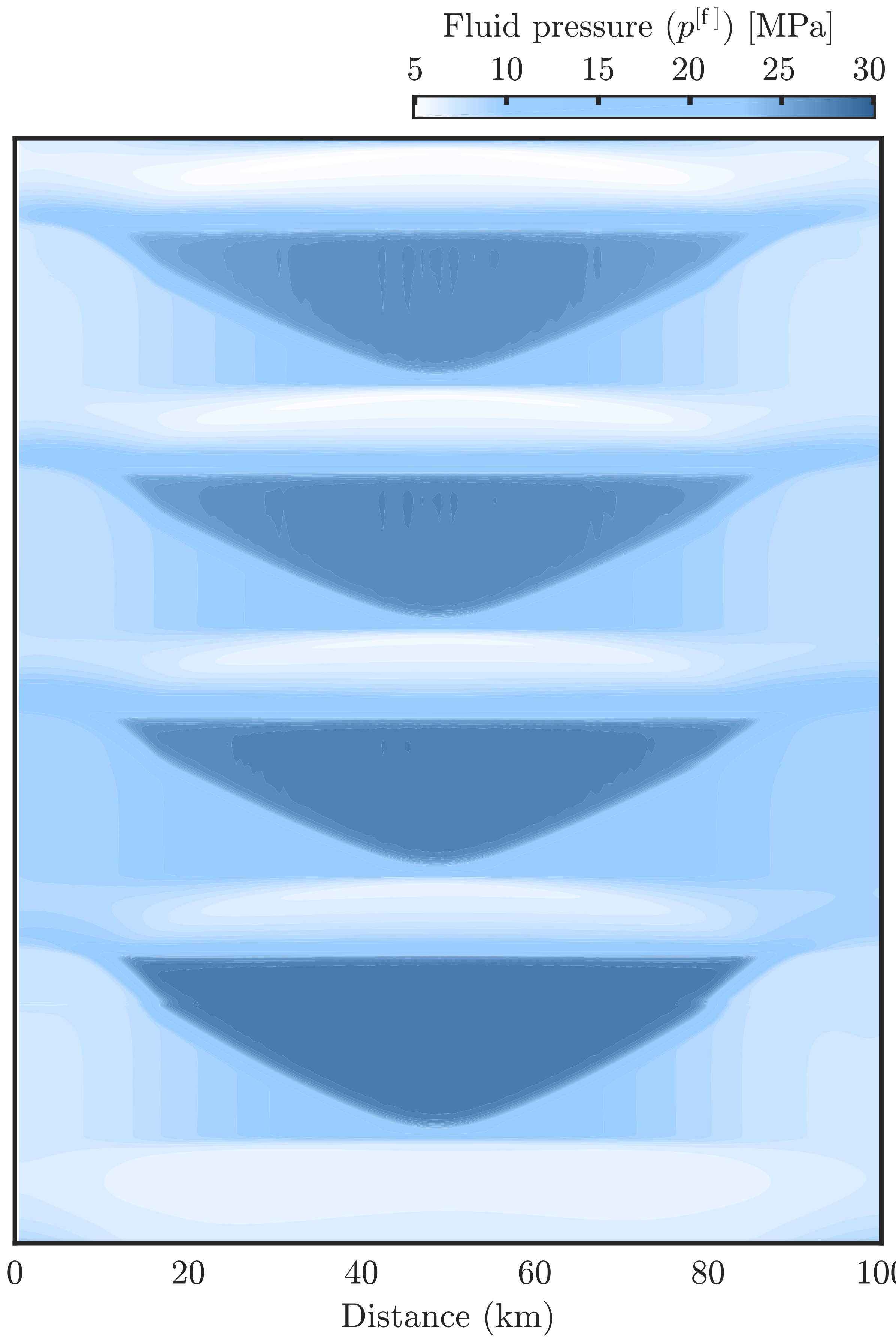



***ArXiv preprint**: Dal Zilio, L., Hegyi, B., Behr, W., & Gerya, T. (2022)*
*Hydro-mechanical earthquake cycles in a poro-visco-elasto-plastic fluid-bearing fault structure.*

# H-MECs: Hydro-Mechanical Earthquake Cycles



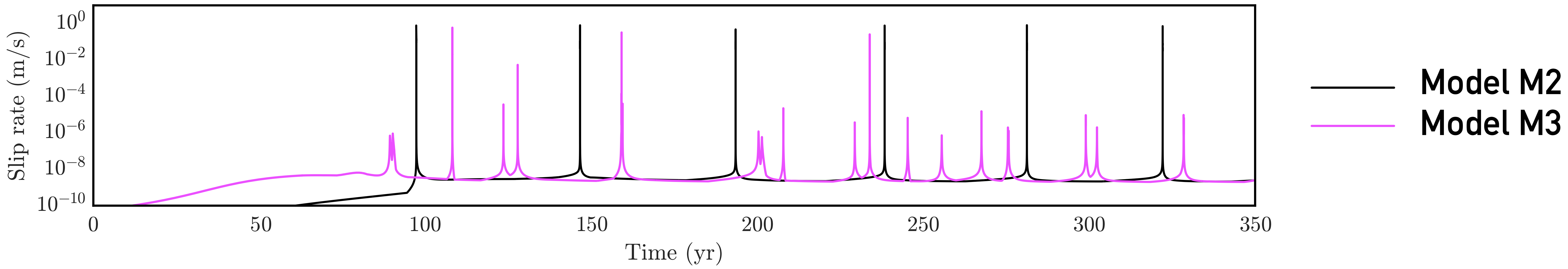



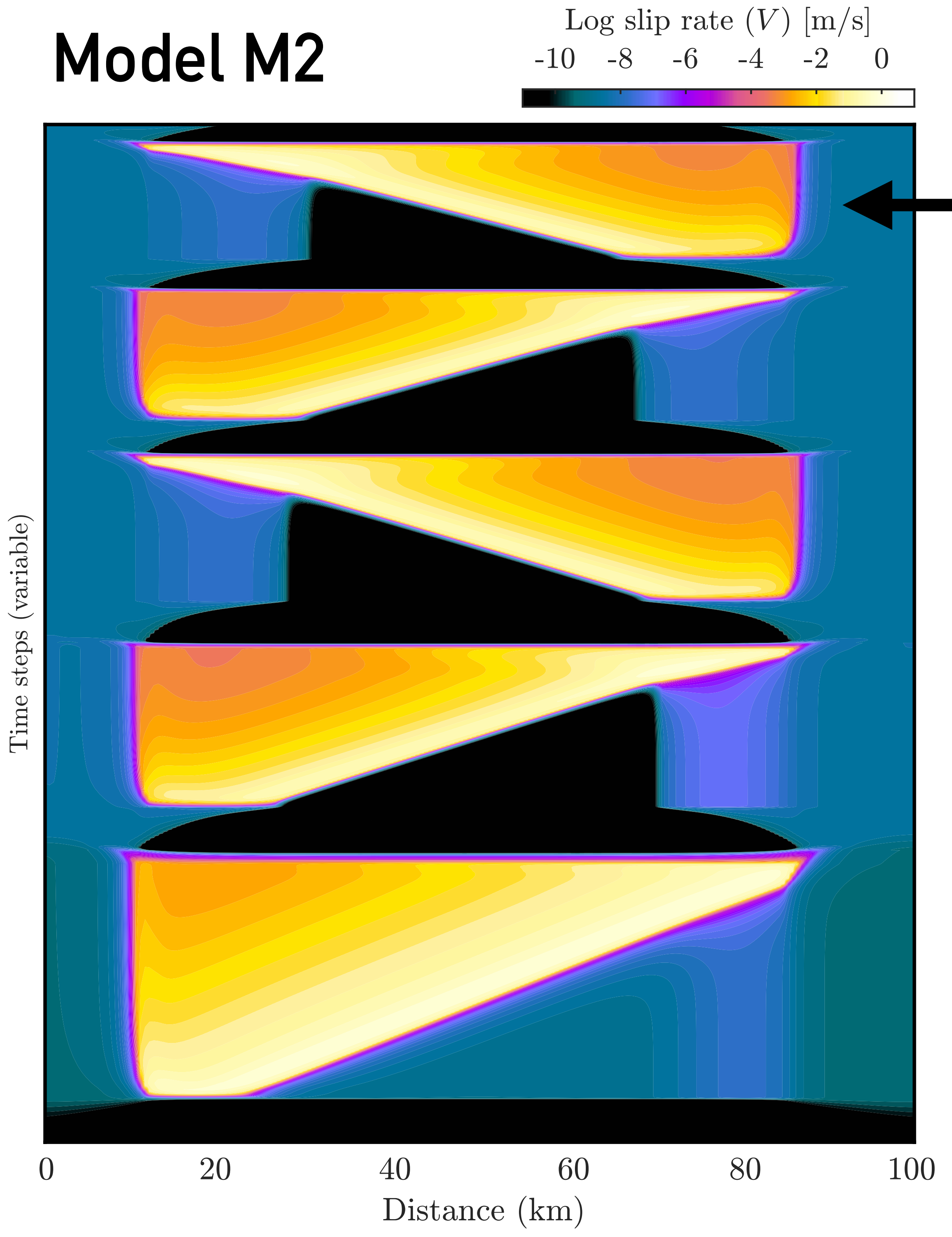

- The model yields regular cycles of complete fault ruptures
- Slip rate and the adaptive time-stepping vary by several orders of magnitude, from ~cm/yr to ~m/s, and from years to milliseconds
- Pore-fluid pressure cycling on-fault varies by several MPa, while pore-pressure diffusion occurs over longer time scales

$$L_c = \frac{\mu\,(\tau_s - \tau_d)\,d_c}{\pi\,(1-\nu)\,(\tau_0 - \tau_d)^2} \quad \text{~7.3 km}$$

*Dal Zilio et al., 2022 (in review)*

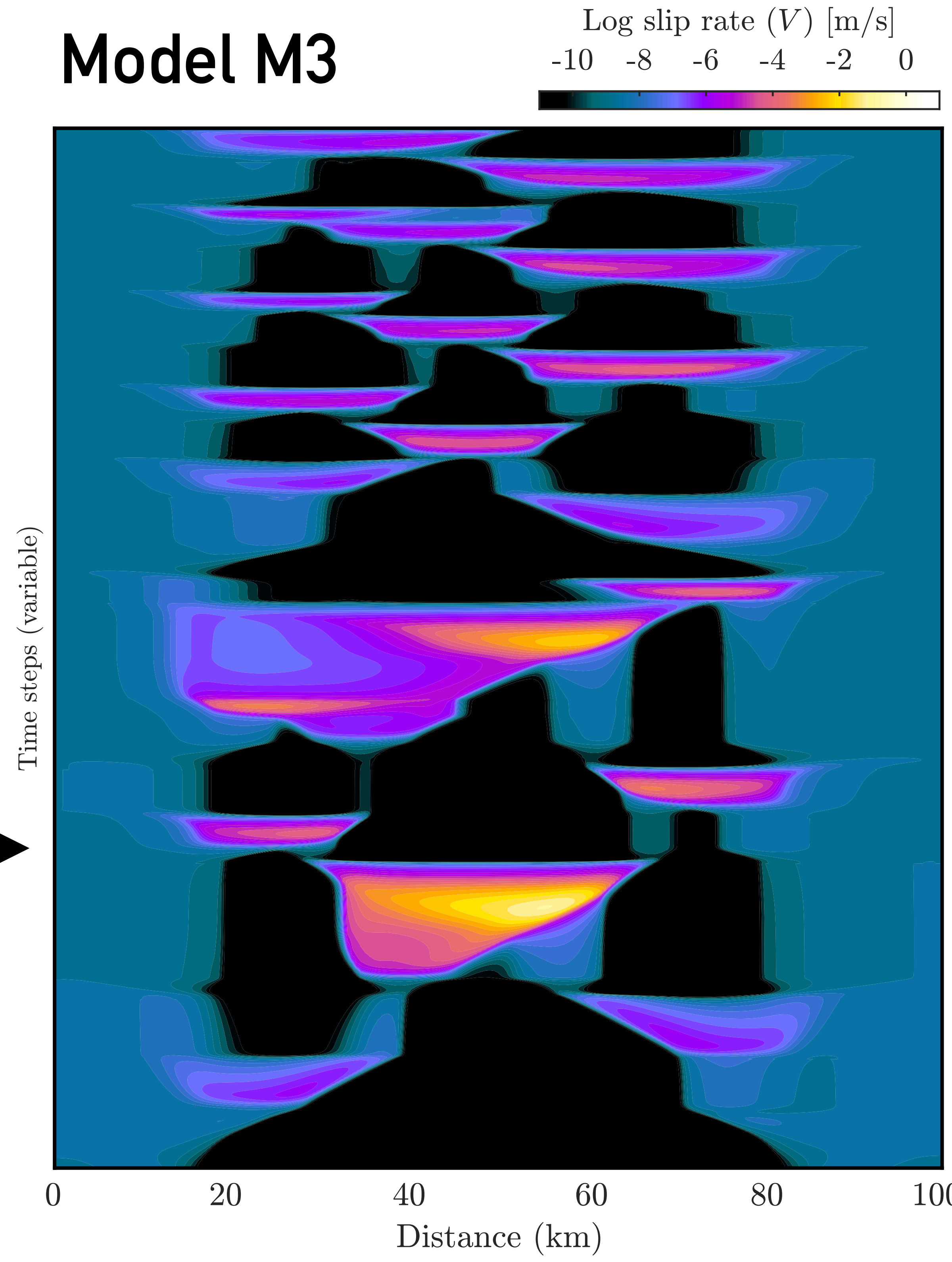
# Fluid-driven slow and fast slip



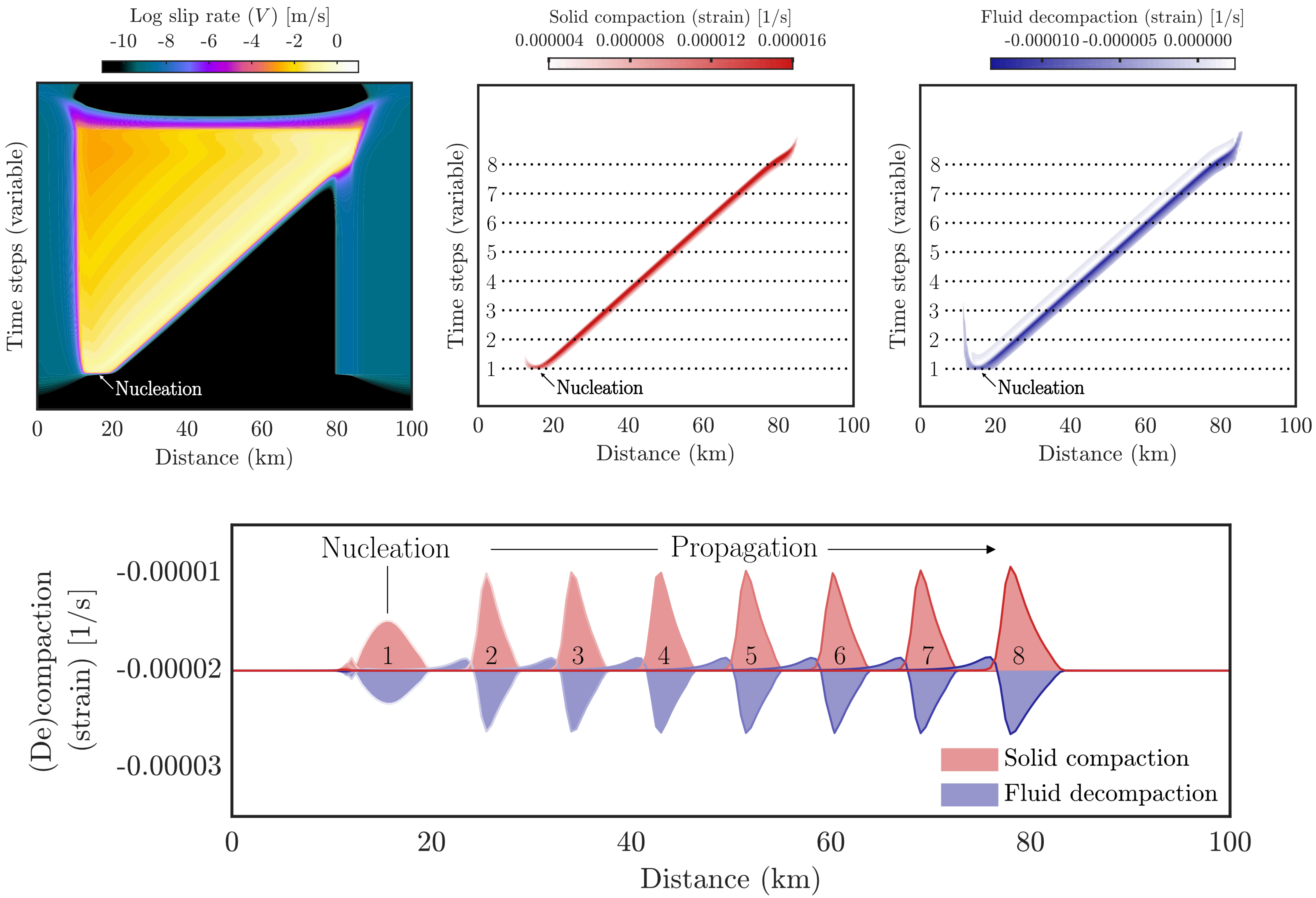

Model M2: lower pore fluid pressure / higher effective normal stress. Smaller nucleation size. As a results, events nucleate from the left or the right transition zones.

Model M3: higher pore fluid pressure / lower effective normal stress. Slow and fast slip events occurs depending on the local pore-fluid pressure.

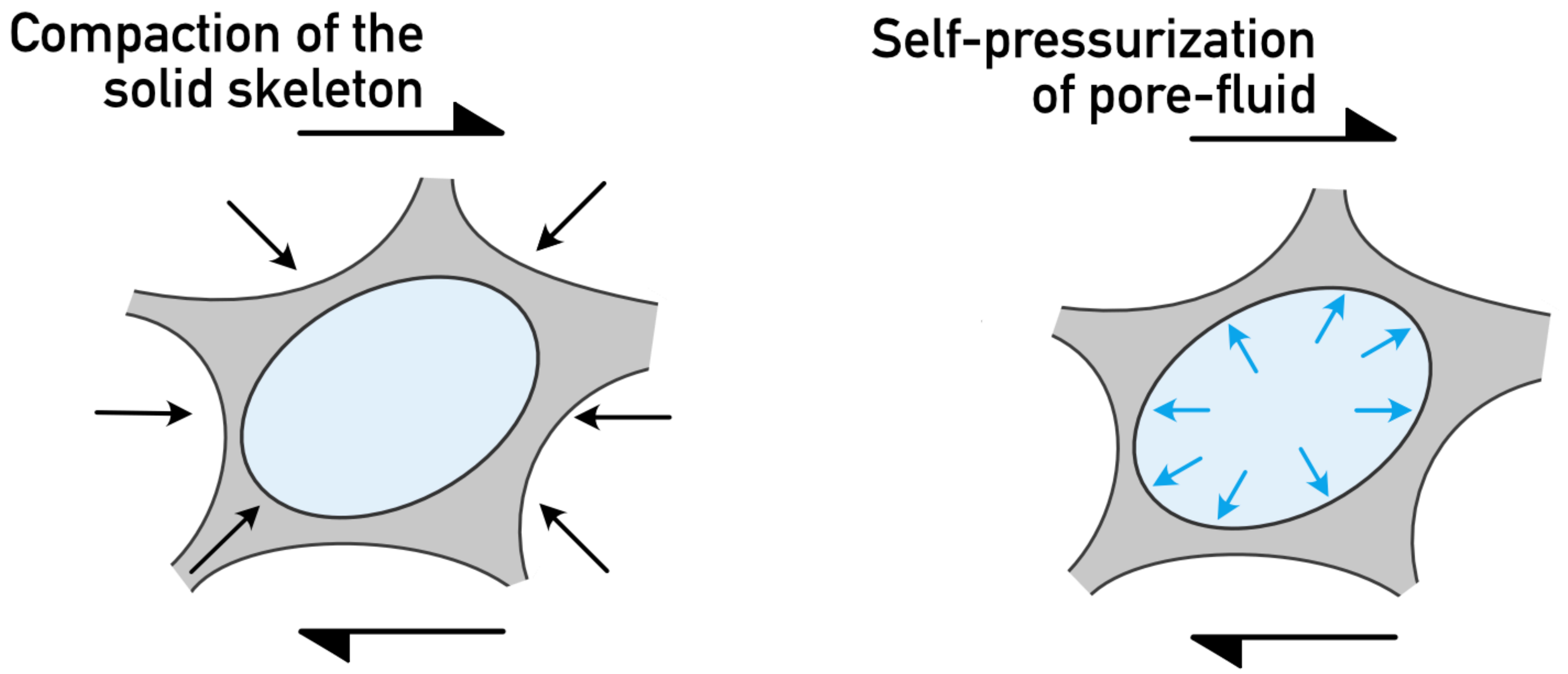



*Dal Zilio et al., 2022 (in review)*

# Dynamic ruptures driven by pore-pressure waves



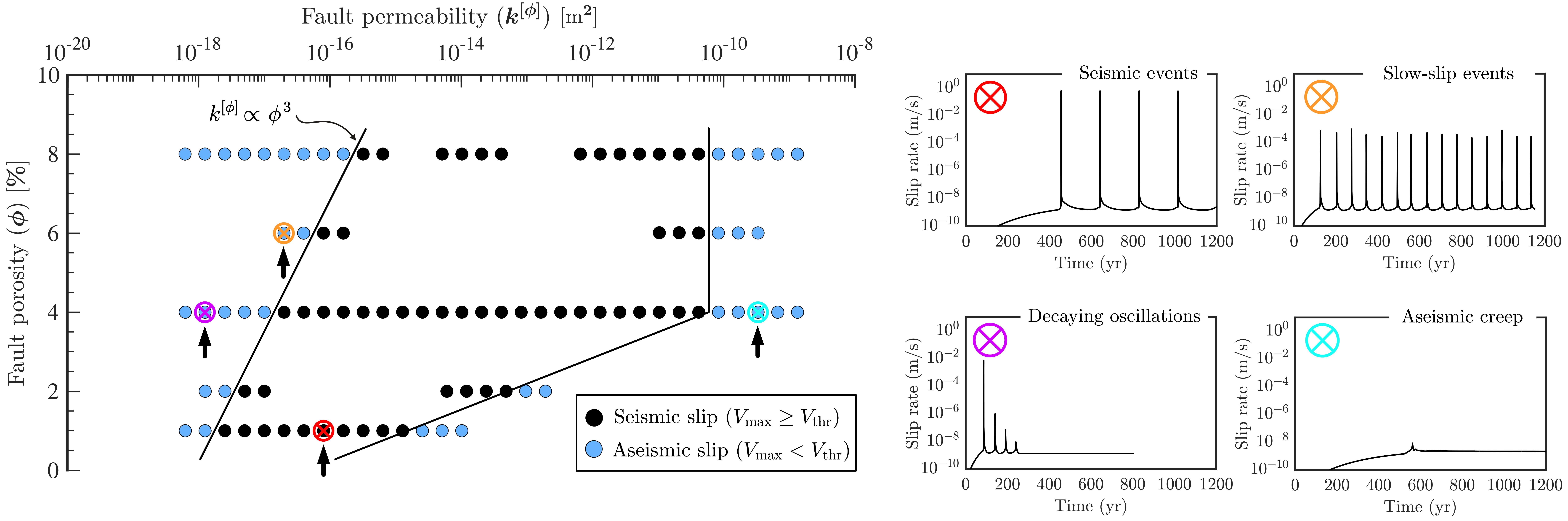

The onset of fluid-driven shear events is controlled by localized compaction of pores and dynamic self-pressurization of fluids inside the undrained fault zone.




Subsequent dynamic ruptures are driven by solitary (pulse-like) pore-pressure waves

*Dal Zilio et al., 2022 (in review)*

# Full spectrum of seismic and aseismic slip




Further parameter analysis shows that the slip response on-fault primarily depends on fault permeability and porosity. 4 slip response patterns are revealed by the parameter space, including seismic events, slow-slip events, oscillatory decay, and stable aseismic creep.

*Dal Zilio et al., 2022 (in review)*