Scientific Research at the BedrettoLab

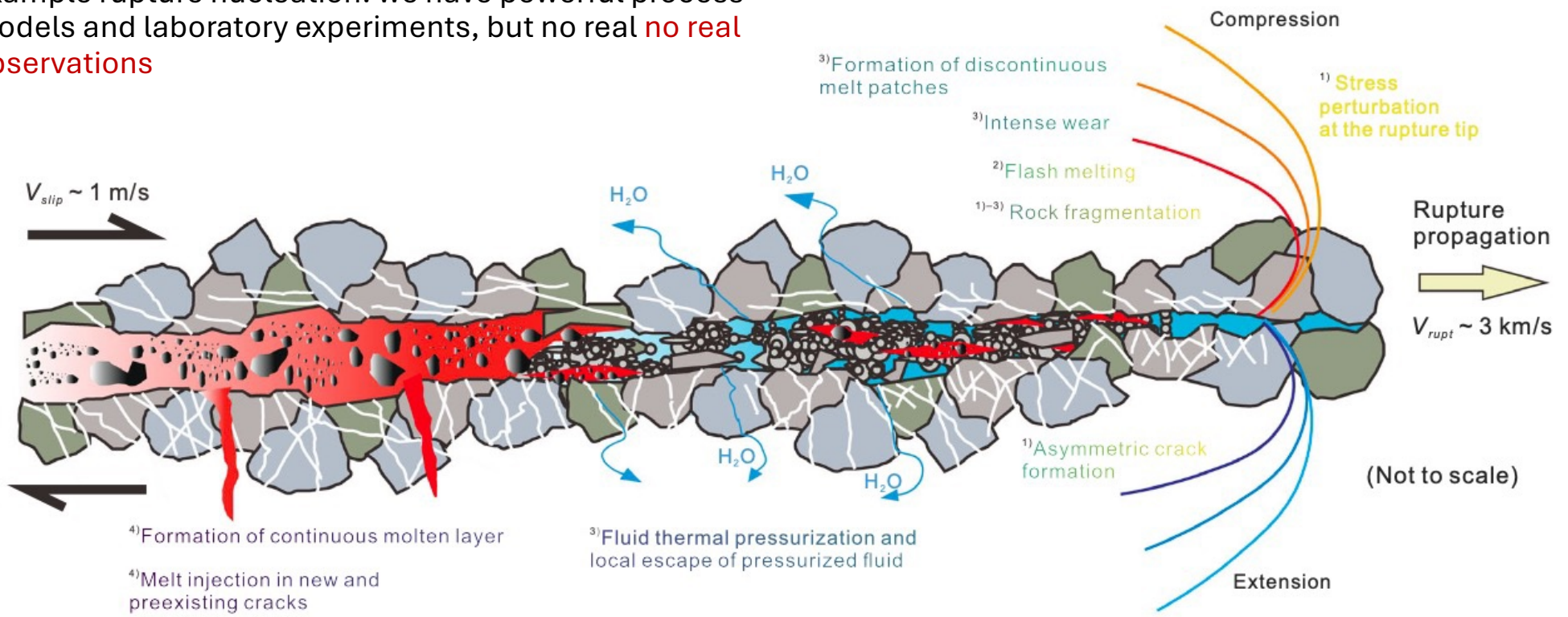
Men-Andrin Meier
for the BedrettoLab and FEAR science teams



Can we resolve rupture physics of real earthquakes?

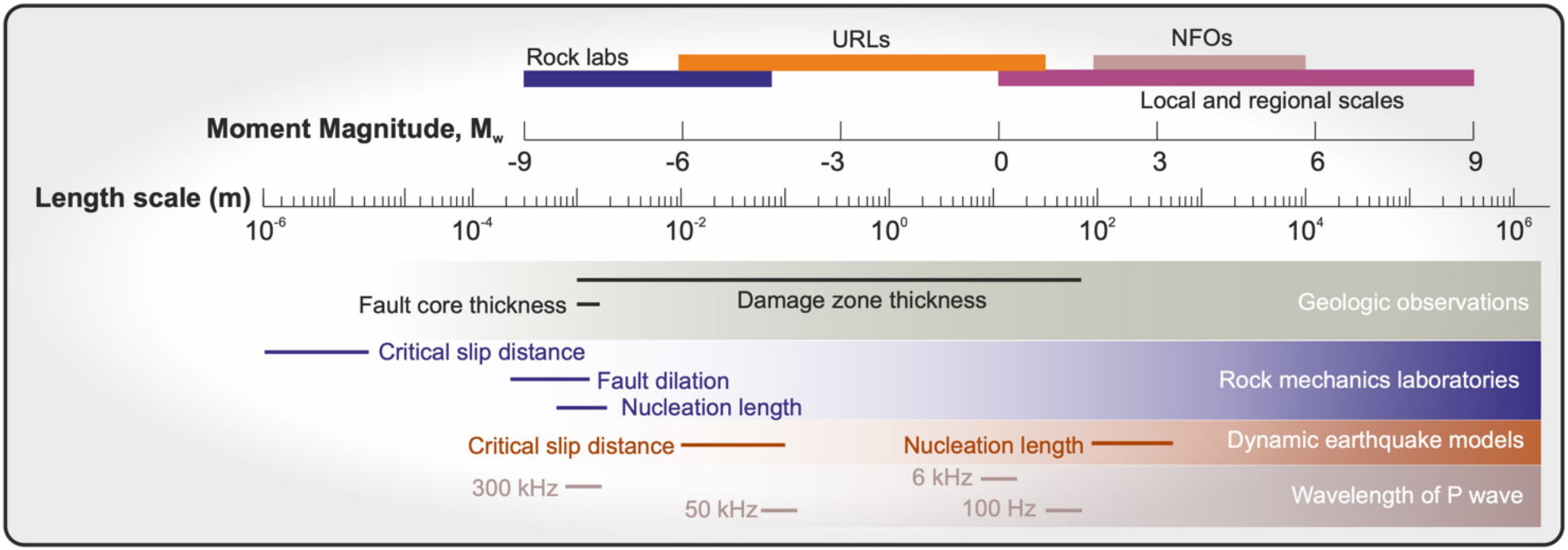
Massive discrepancy between numerical models, laboratory experiments & observations

Example rupture nucleation: we have powerful process models and laboratory experiments, but no real no real observations



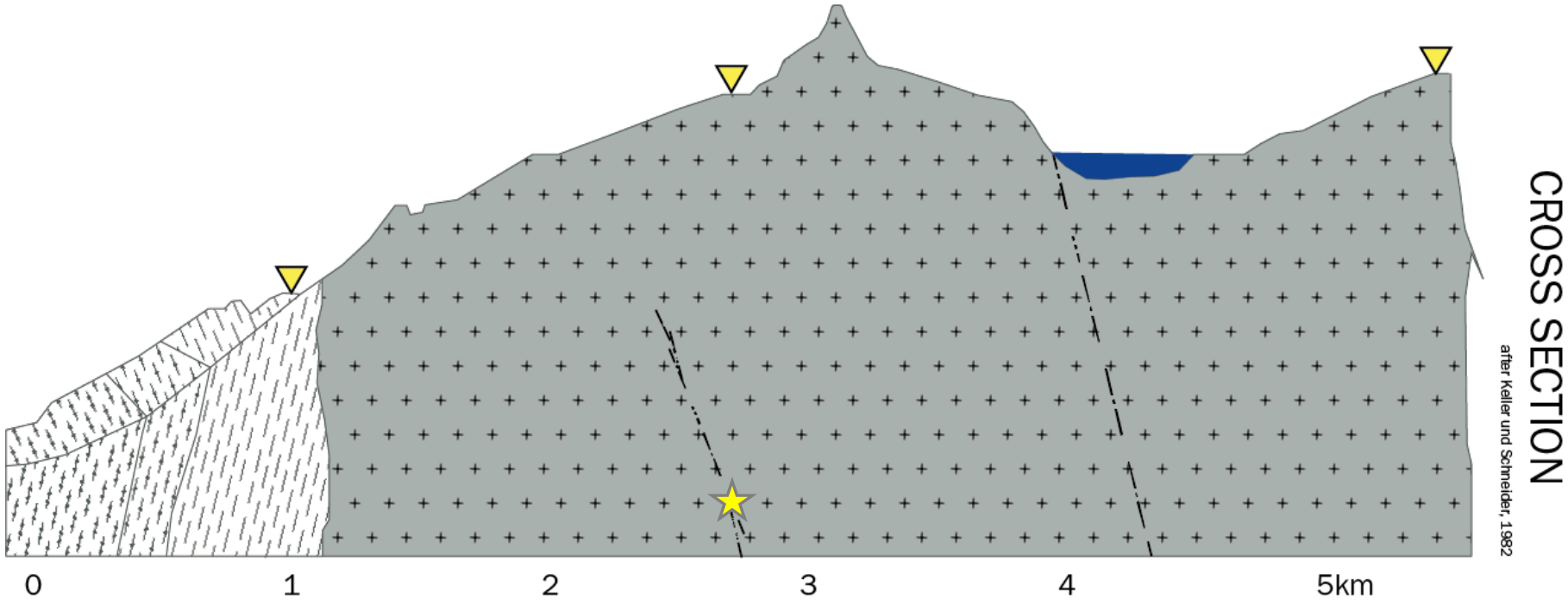
Yao et al., 2023, Nat. Com.

Can we resolve rupture physics of real earthquakes?



Meier, Selvadurai, Dal Zilio, Ellsworth, Bohnhoff, Supino, Ide, Savage, Ma, Ammann, Cocco, Wiemer & Giardini, in prep.

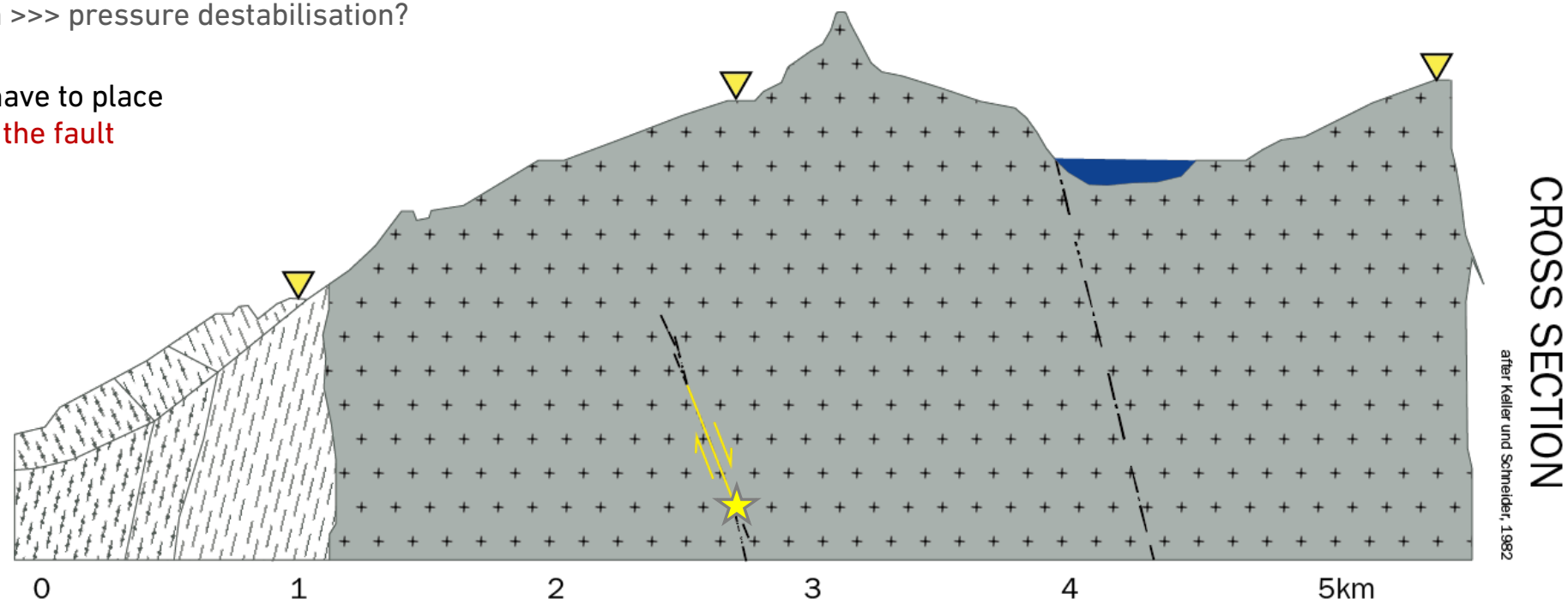
Can we resolve rupture physics of real earthquakes?



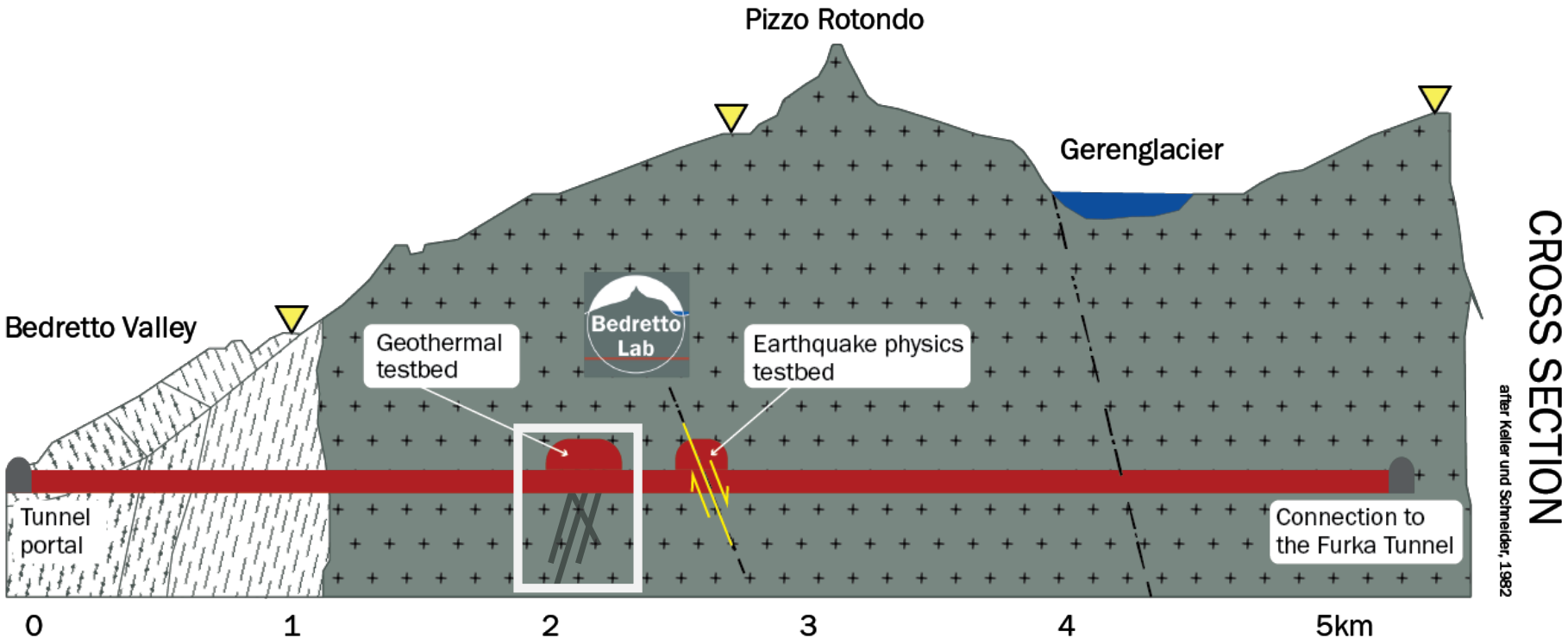
Can we resolve rupture physics of real earthquakes?

Fluids?
Aseismic slip ?
Tiny foreshocks?
Initial Dilation?
Compaction >>> pressure destabilisation?

We would have to place sensors *on* the fault



The Bedretto Underground Laboratory for Geosciences and Geoenergies

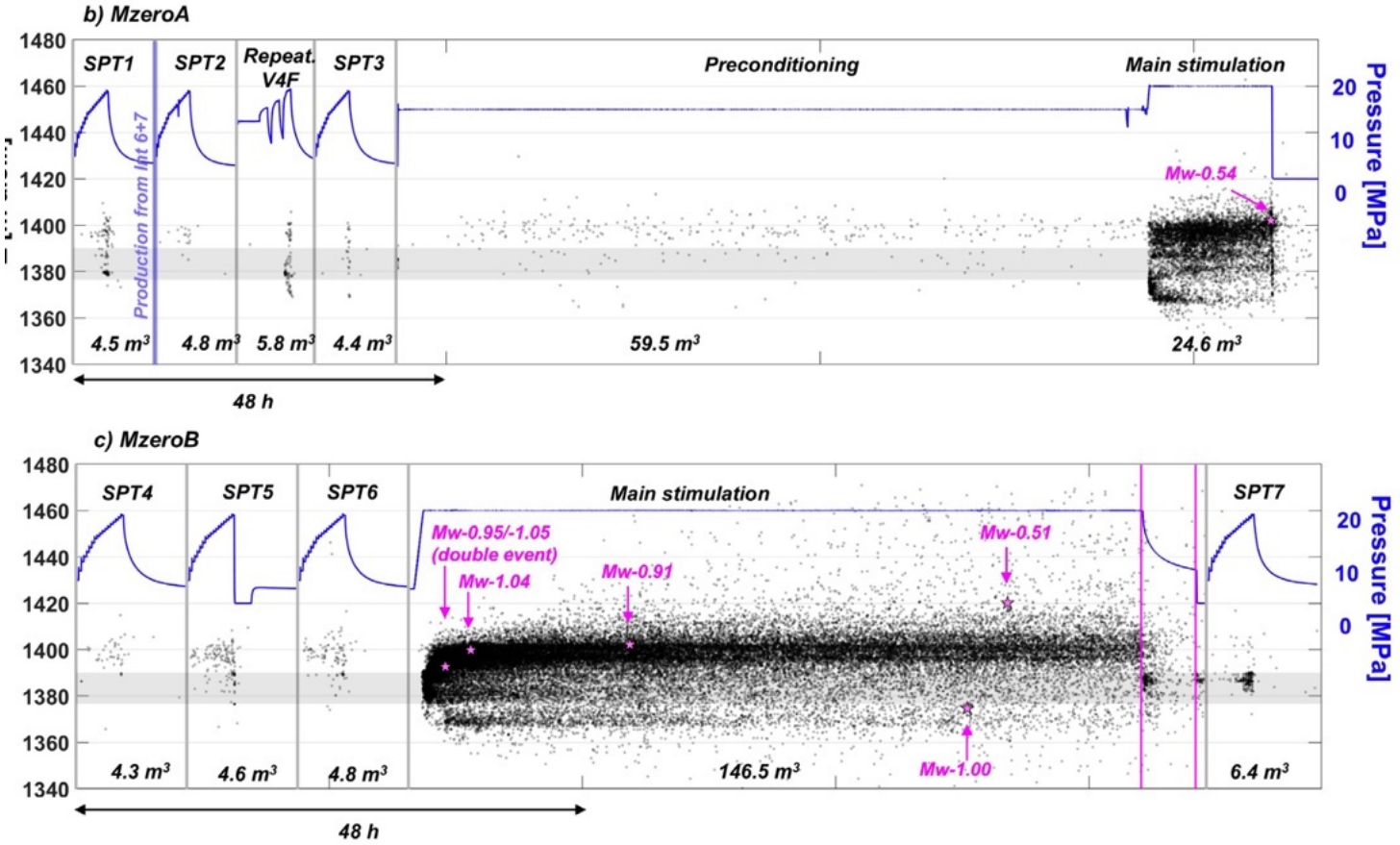


How to manage earthquake risk in geoenergy projects?

- How to prevent larger magnitude earthquakes in fluid injection projects?
- We may first need to understand how we can trigger larger* quakes!

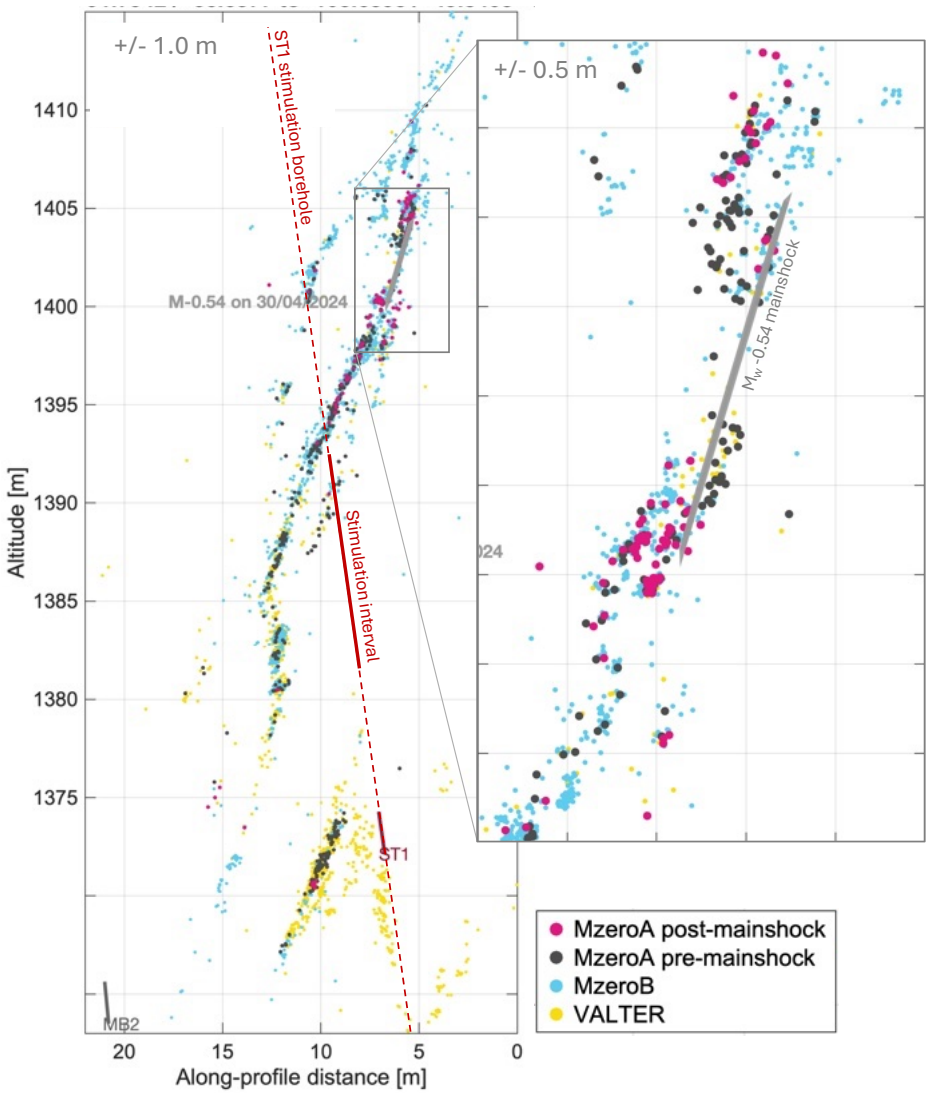
* “larger” quakes for a lab environment. much smaller than anything that can be felt at the surface

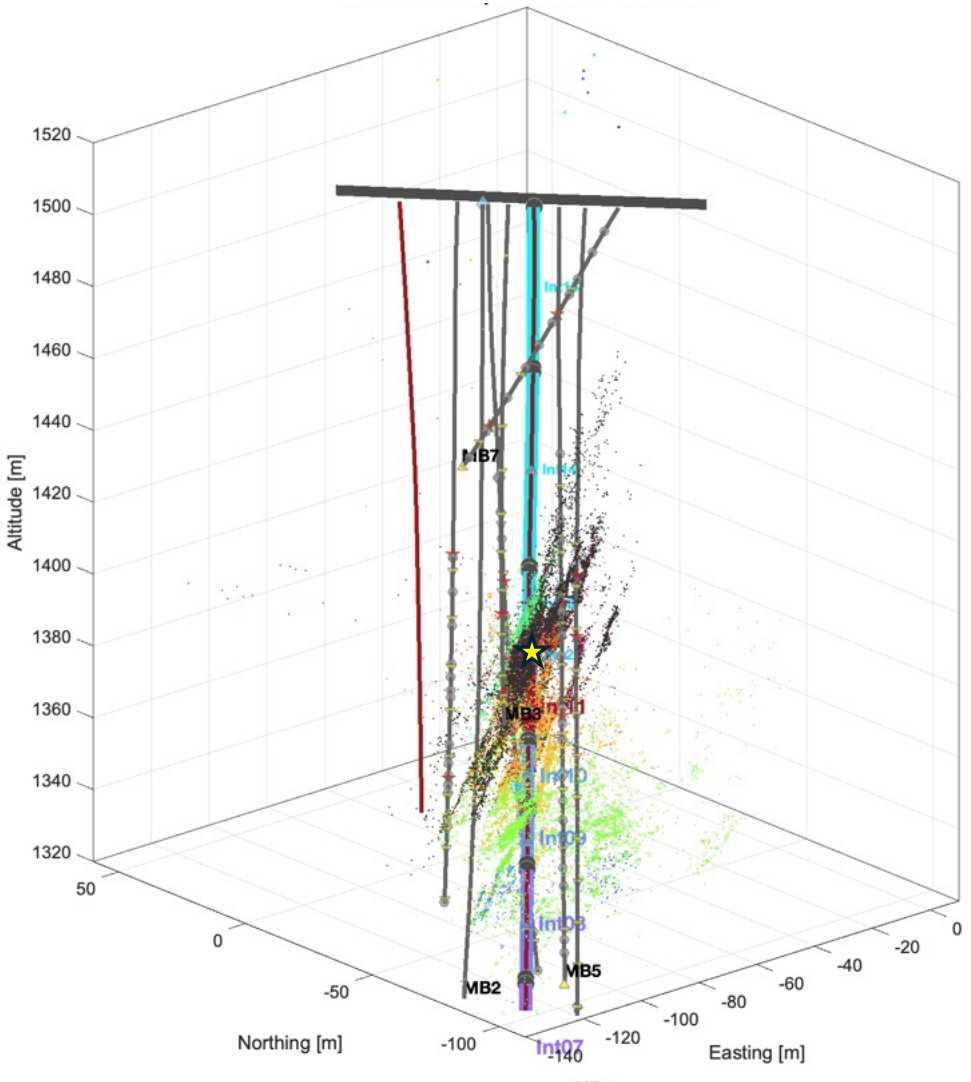
The »Mzero« experiments



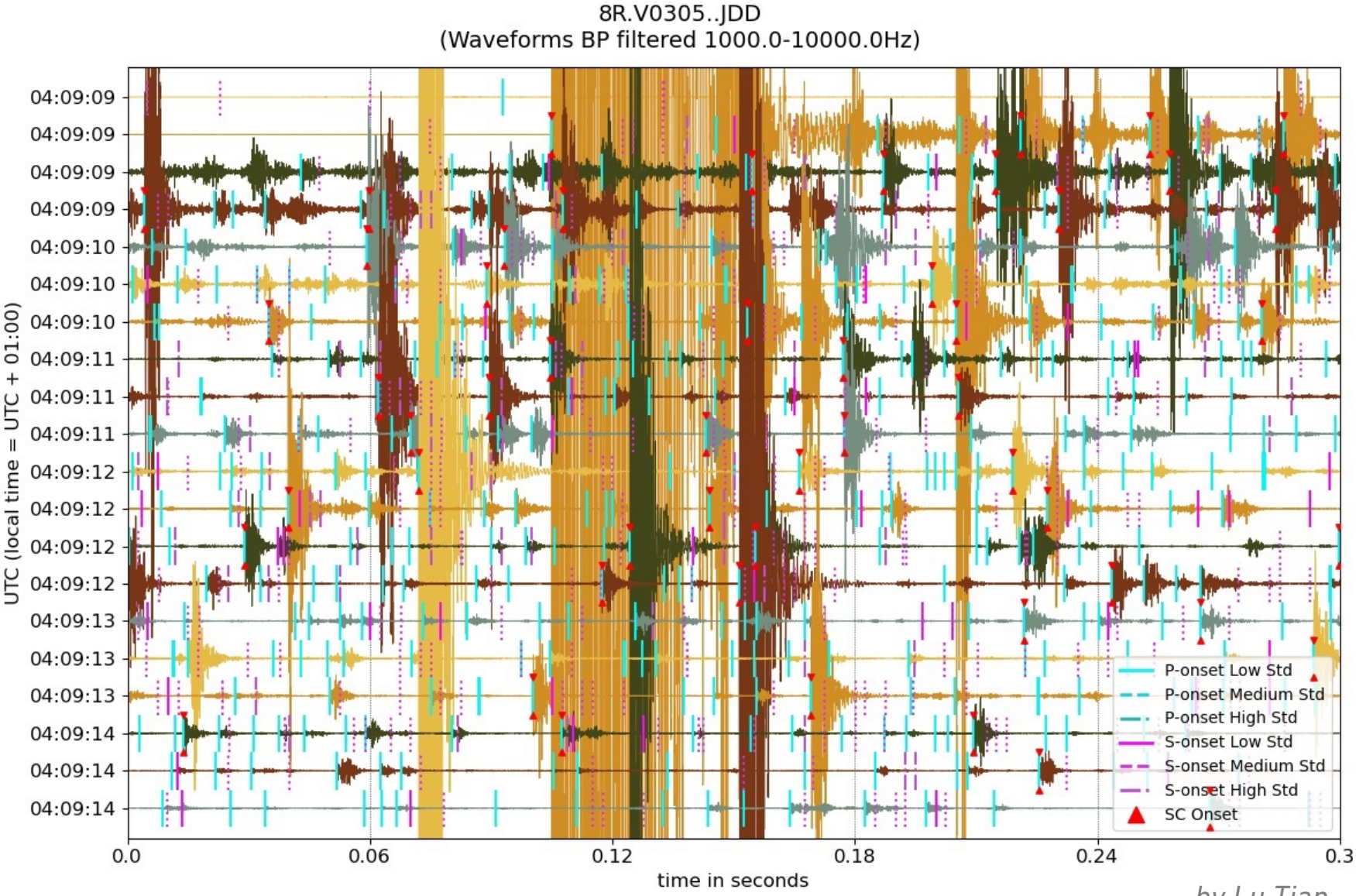
Gischig et al., in rev. with JGR

a) Vertical profile

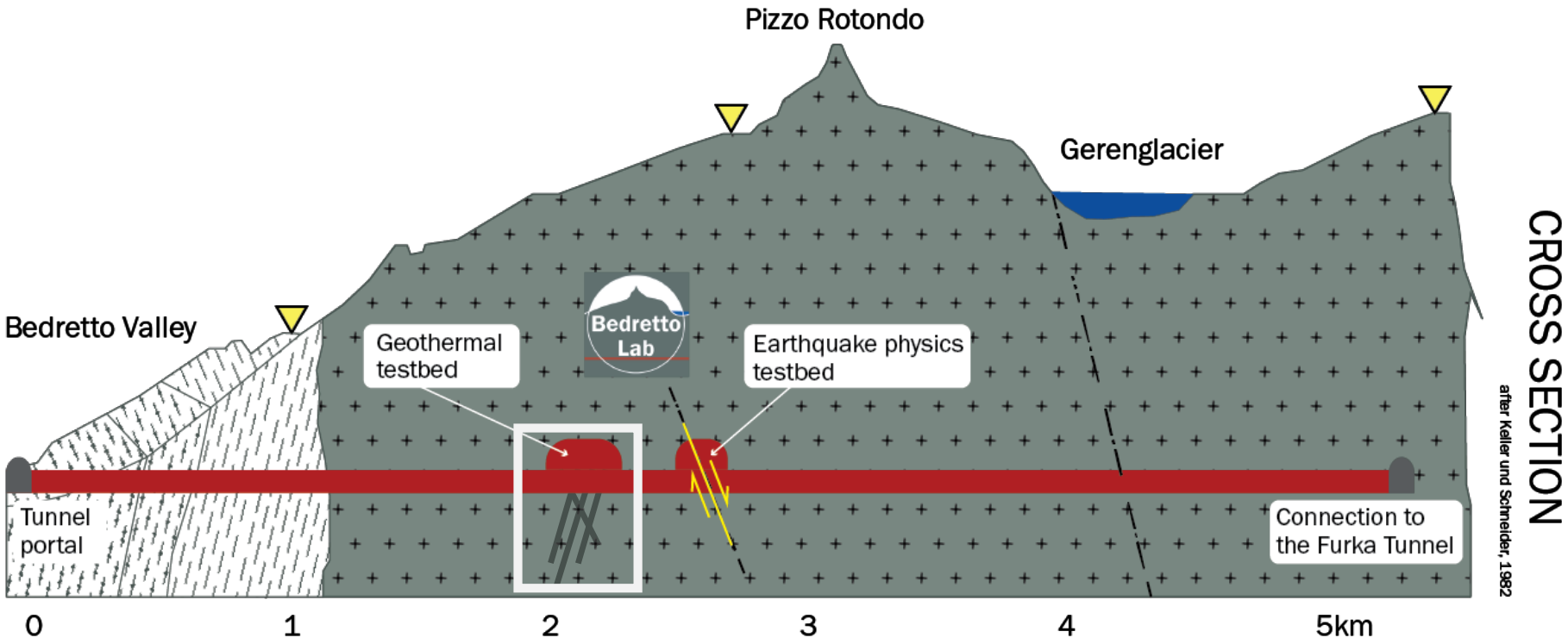




Meier, Gischig et al., in prep.


8R.V0305..JDD
(Waveforms BP filtered 1000.0-10000.0Hz)
UTC (local time = UTC + 01:00)
04:09:09
04:09:09
04:09:09
04:09:09
04:09:10
04:09:10
04:09:10
04:09:11
04:09:11
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04:09:13
04:09:13
04:09:14
04:09:14
04:09:14
0.0
0.06
0.12
0.18
0.24
0.3
time in seconds
P-onset Low Std
P-onset Medium Std
P-onset High Std
S-onset Low Std
S-onset Medium Std
S-onset High Std
SC Onset
by Lu Tian

The Earthquake Physics Testbed



The Earthquake Physics Testbed

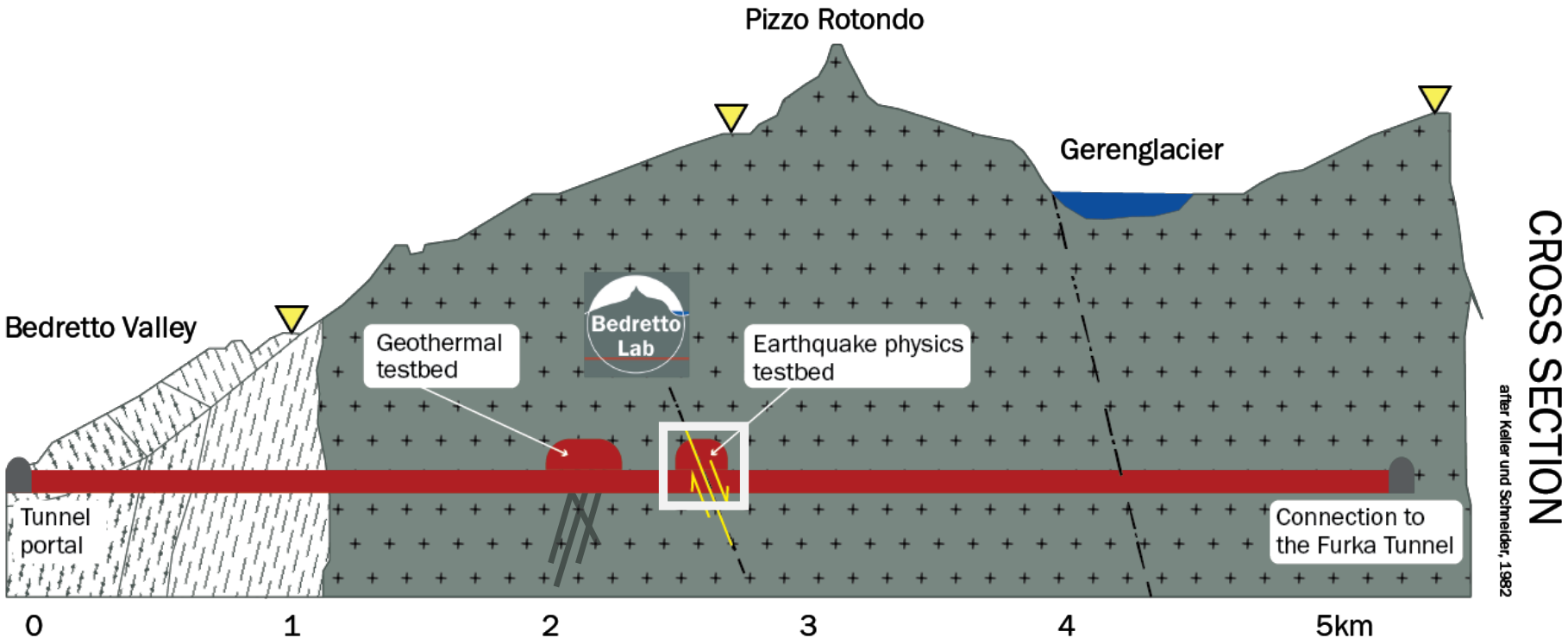
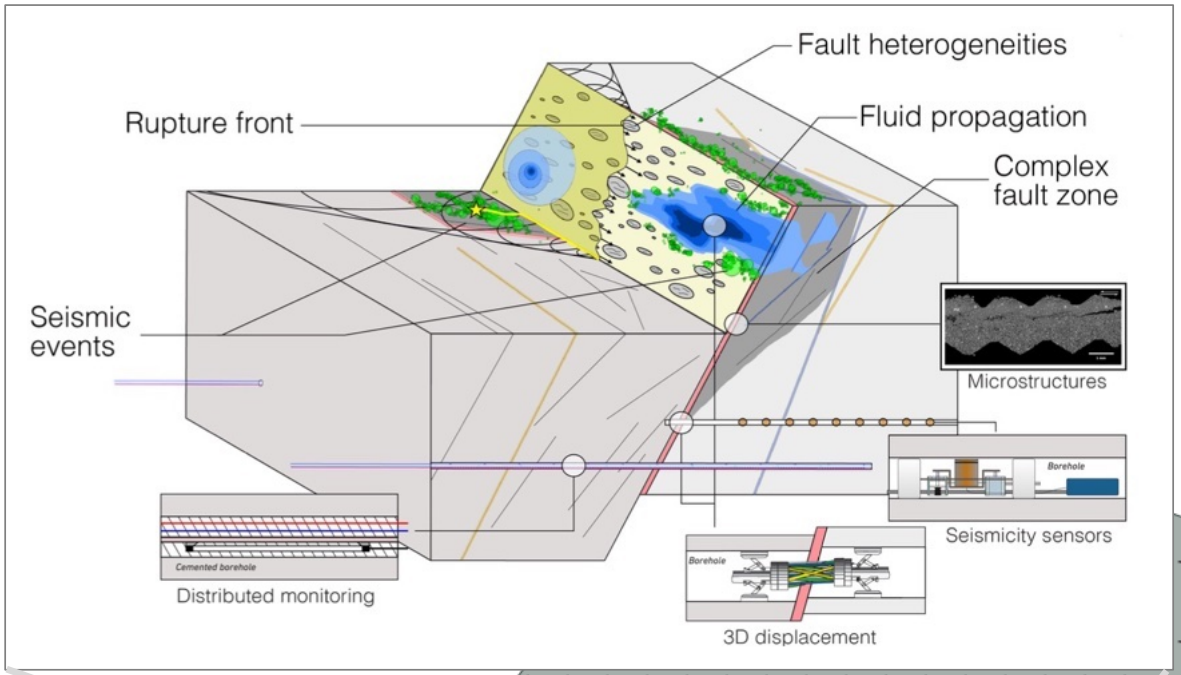


Figure by Alberto Ceccato & Paul Selvadurai



Fault Activation and Earthquake Rupture ("FEAR")

Identify & characterize a target fault zone

Densely instrument it

Make it move! (M_w ~1.0)

Study rupture physics

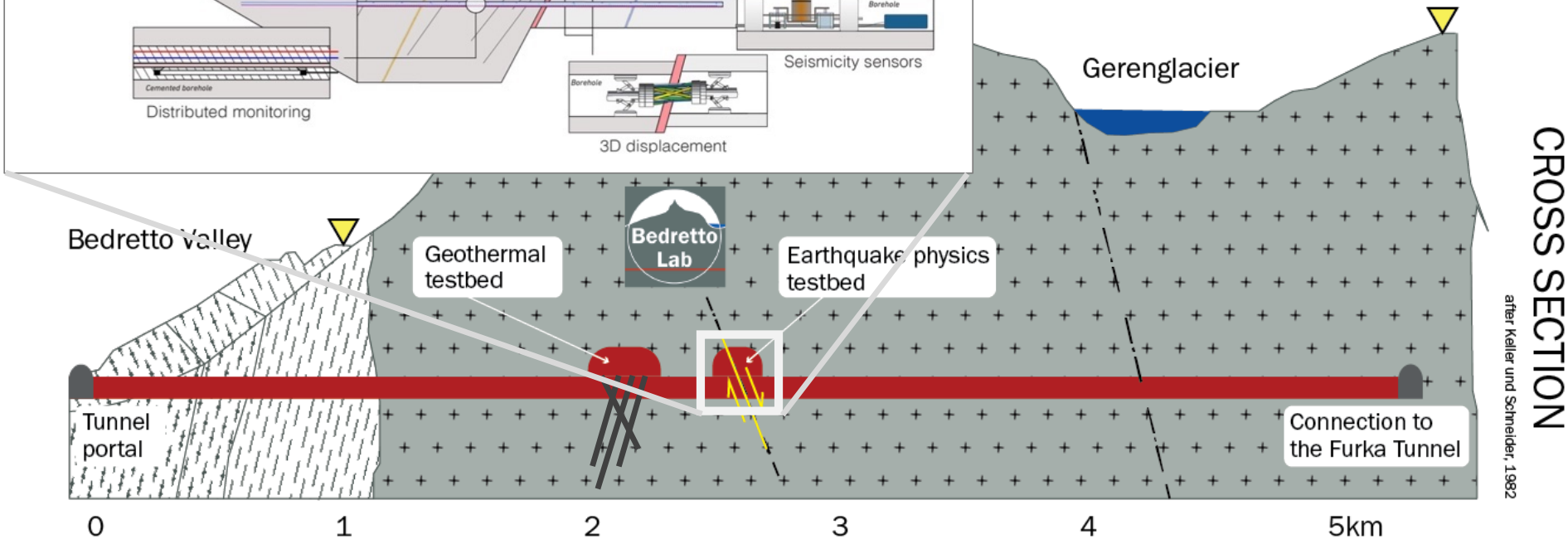
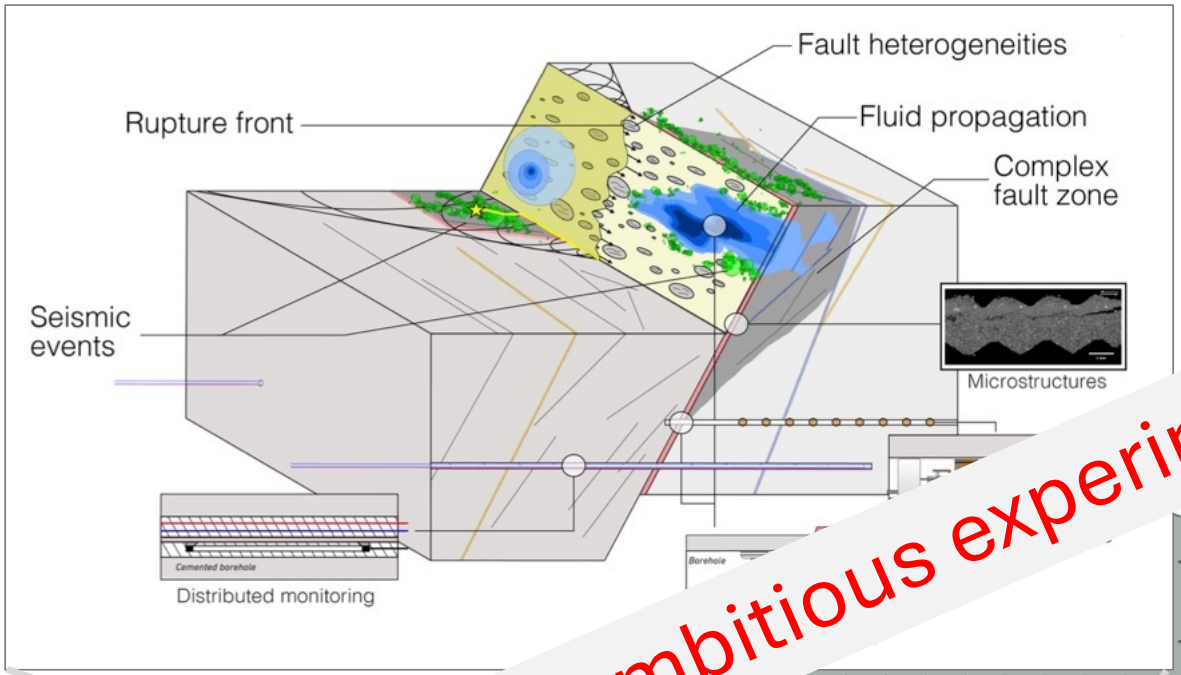


Figure by Alberto Ceccato & Paul Selvadurai



Fault Activation and Earthquake Rupture ("FEAR") project

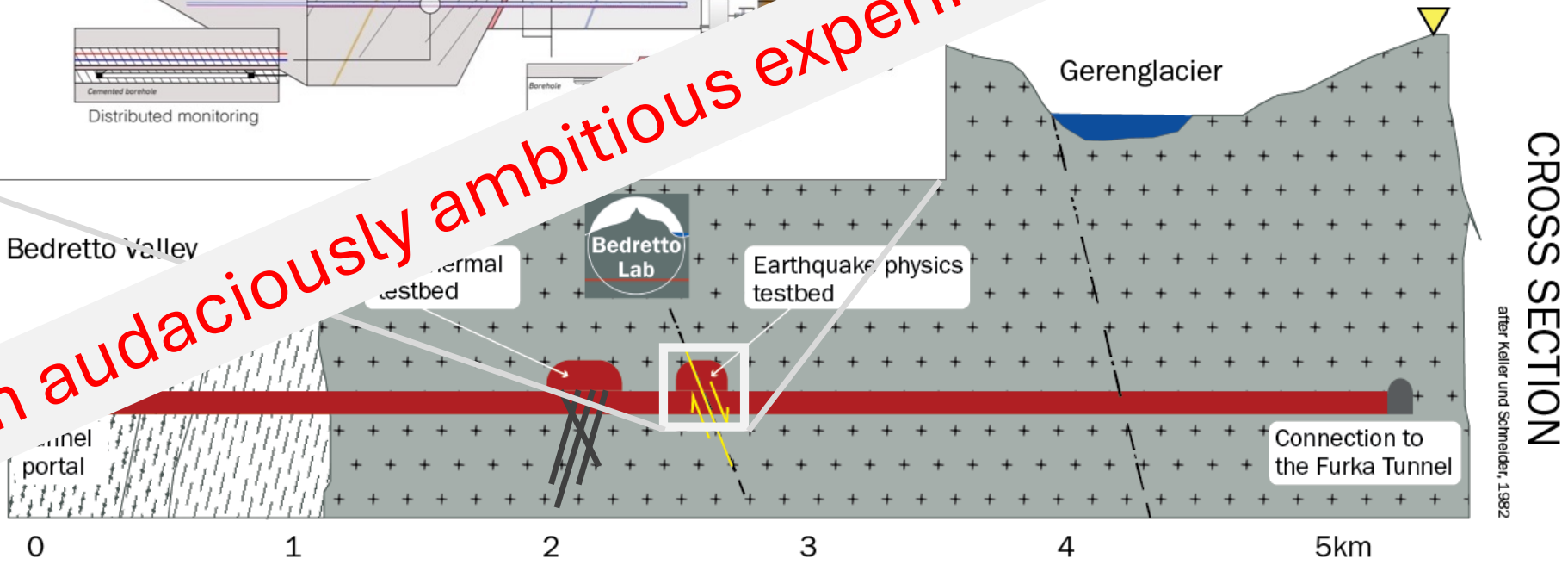
Identify & characterize a ta… one

Densely instrumen…

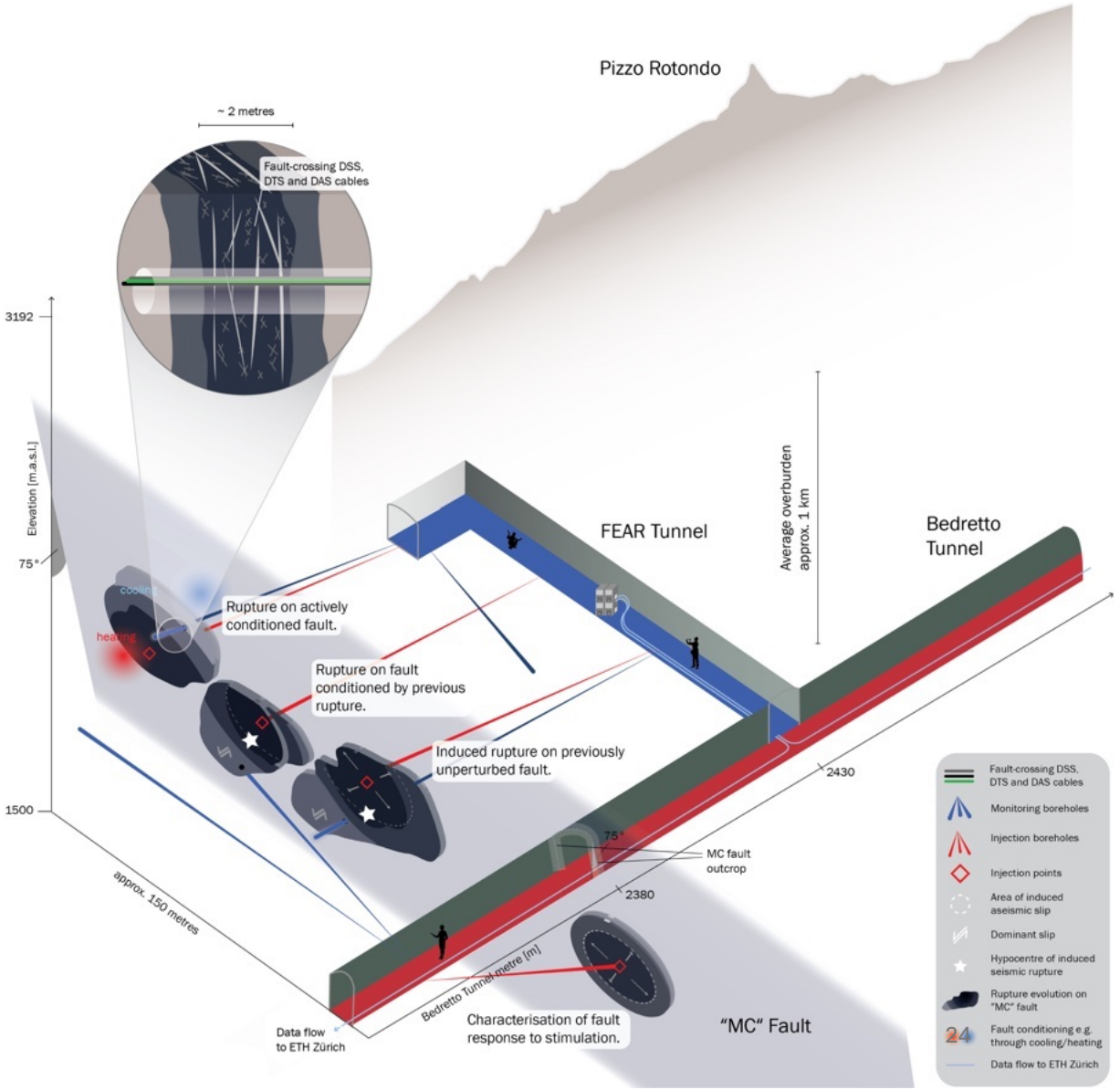
Make it ma…

S… ics

"An audaciously ambitious experiment" - Reviewer B

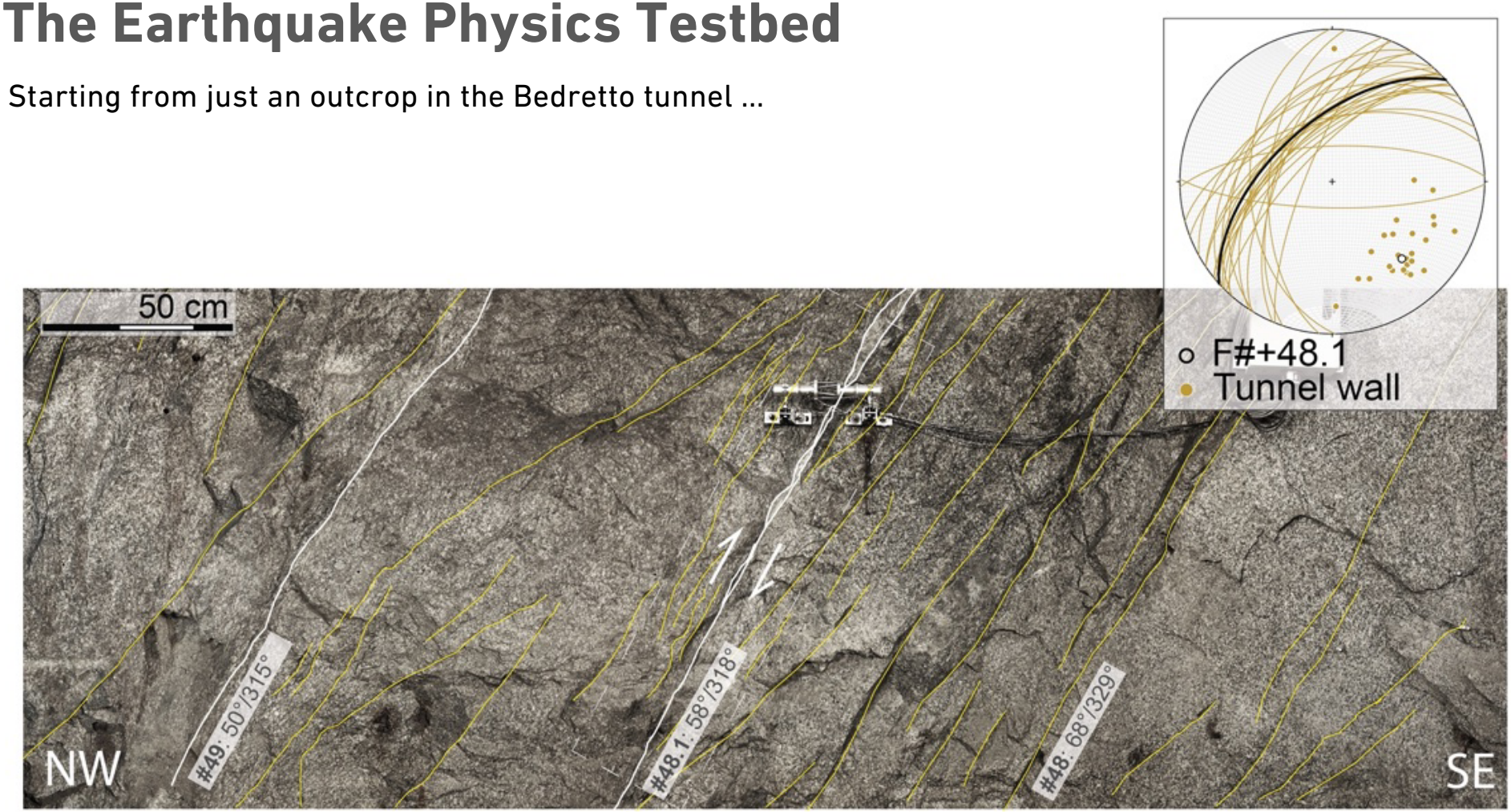


The Earthquake Physics Testbed

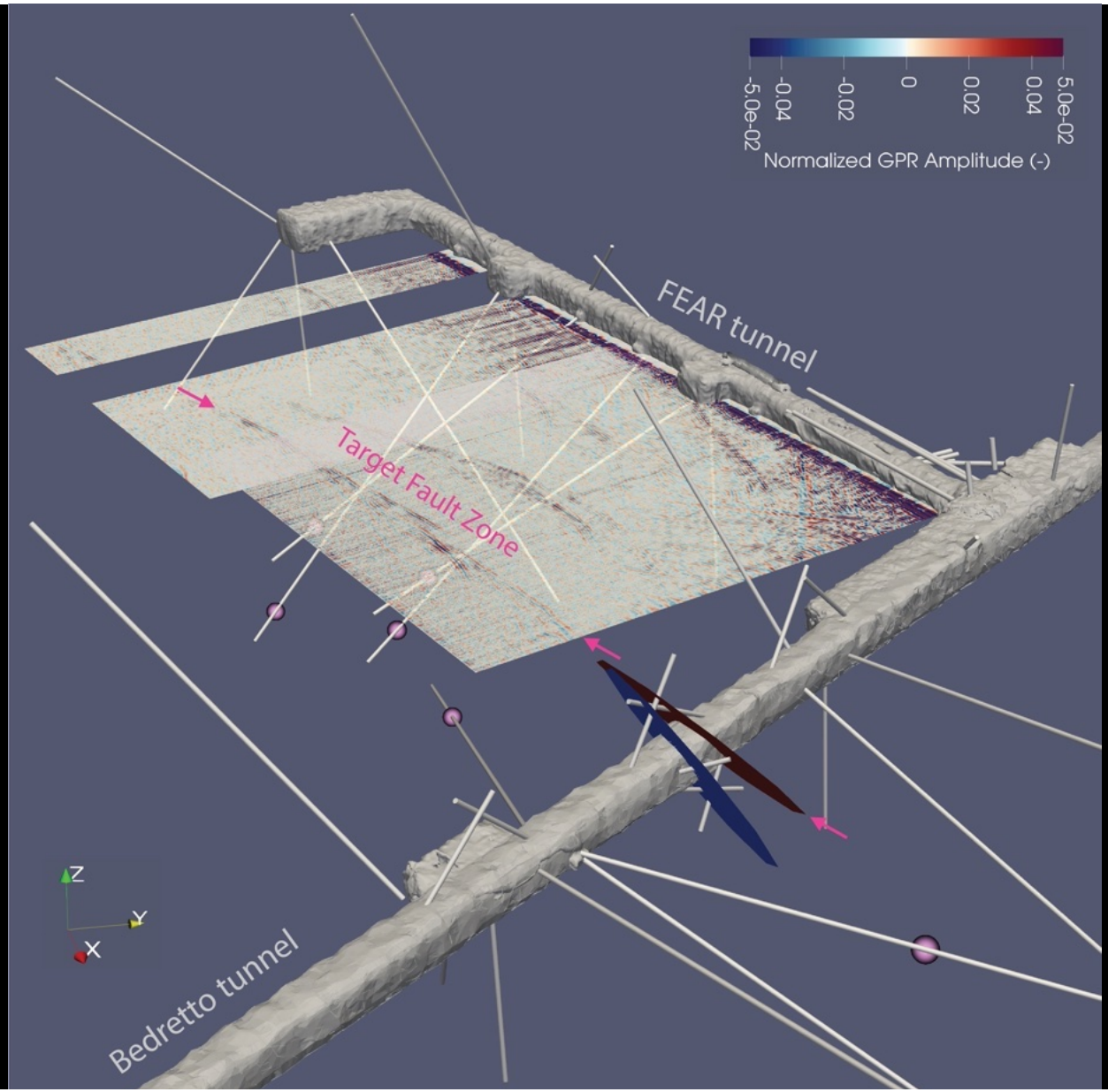


The Earthquake Physics Testbed

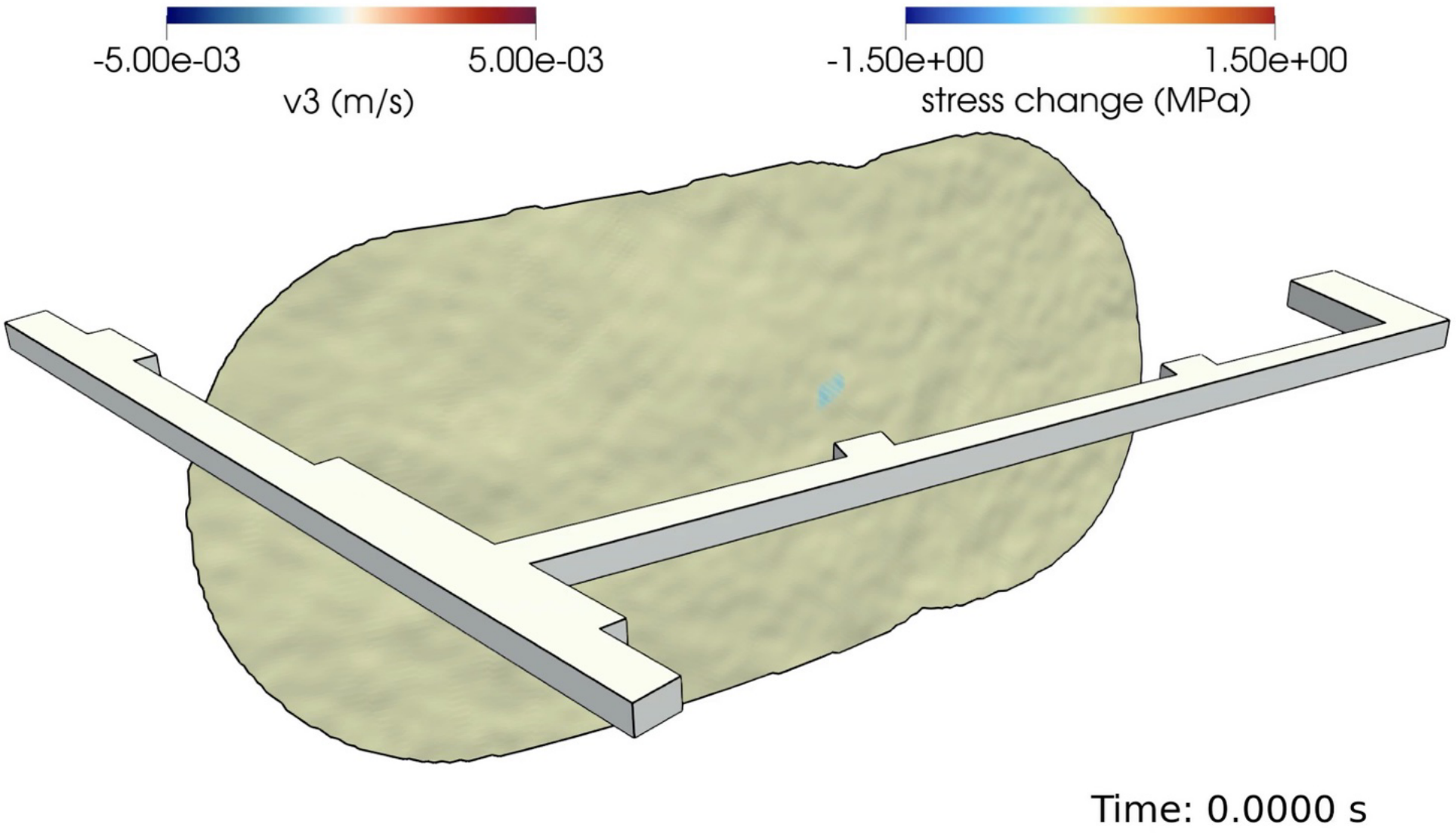
Starting from just an outcrop in the Bedretto tunnel …

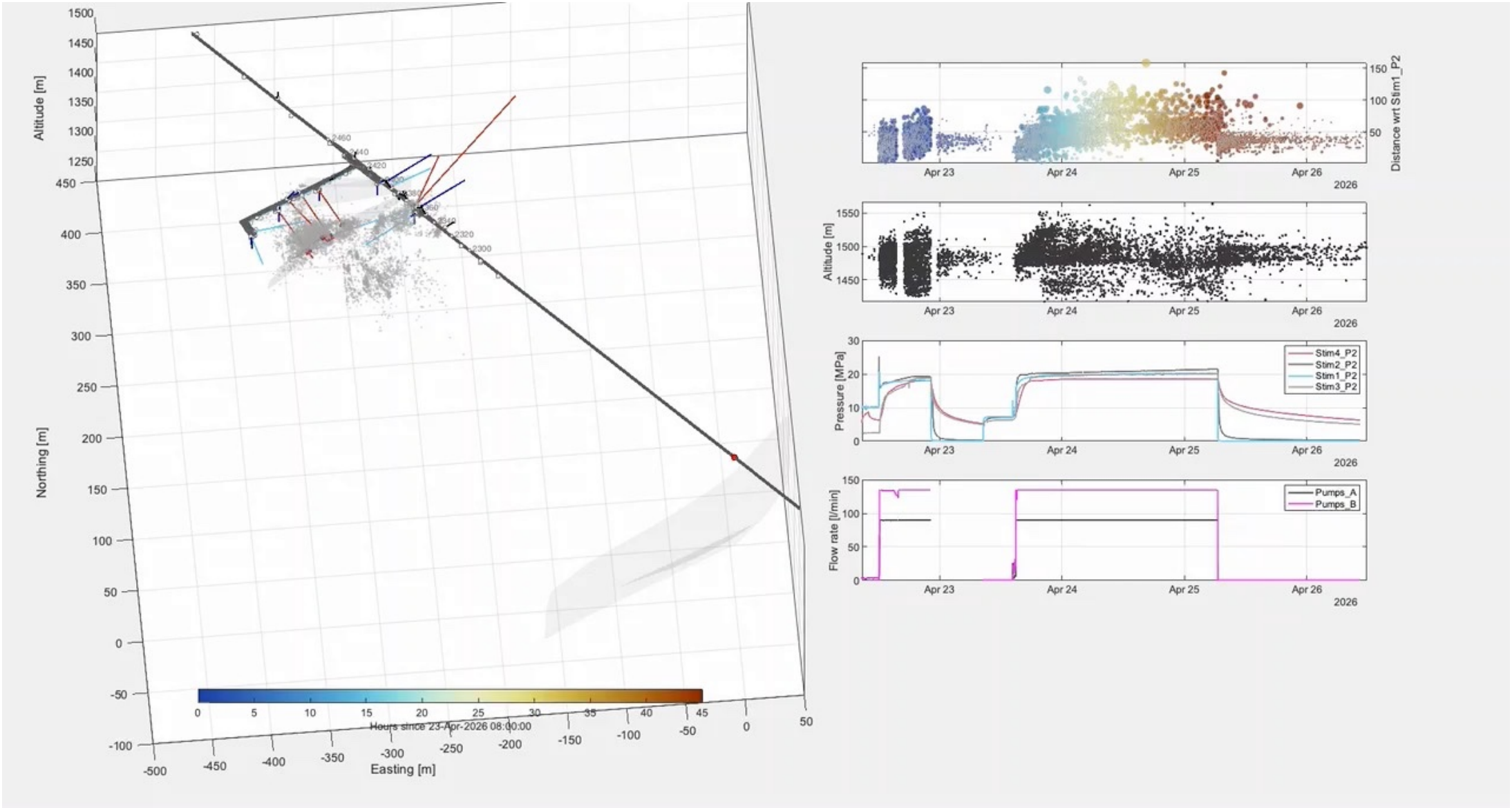


Achtziger-Zupančič et al., 2024, Solid Earth

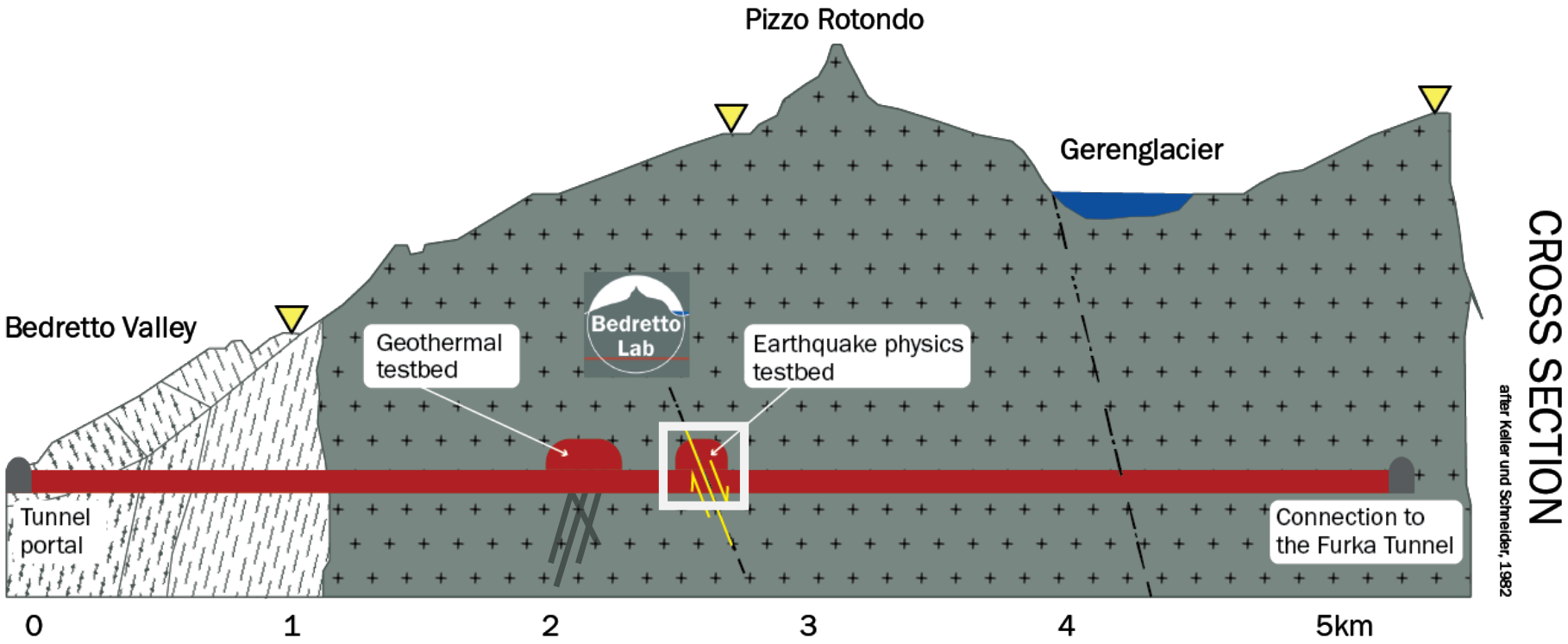


Meier et al., 2026, SEISMICA

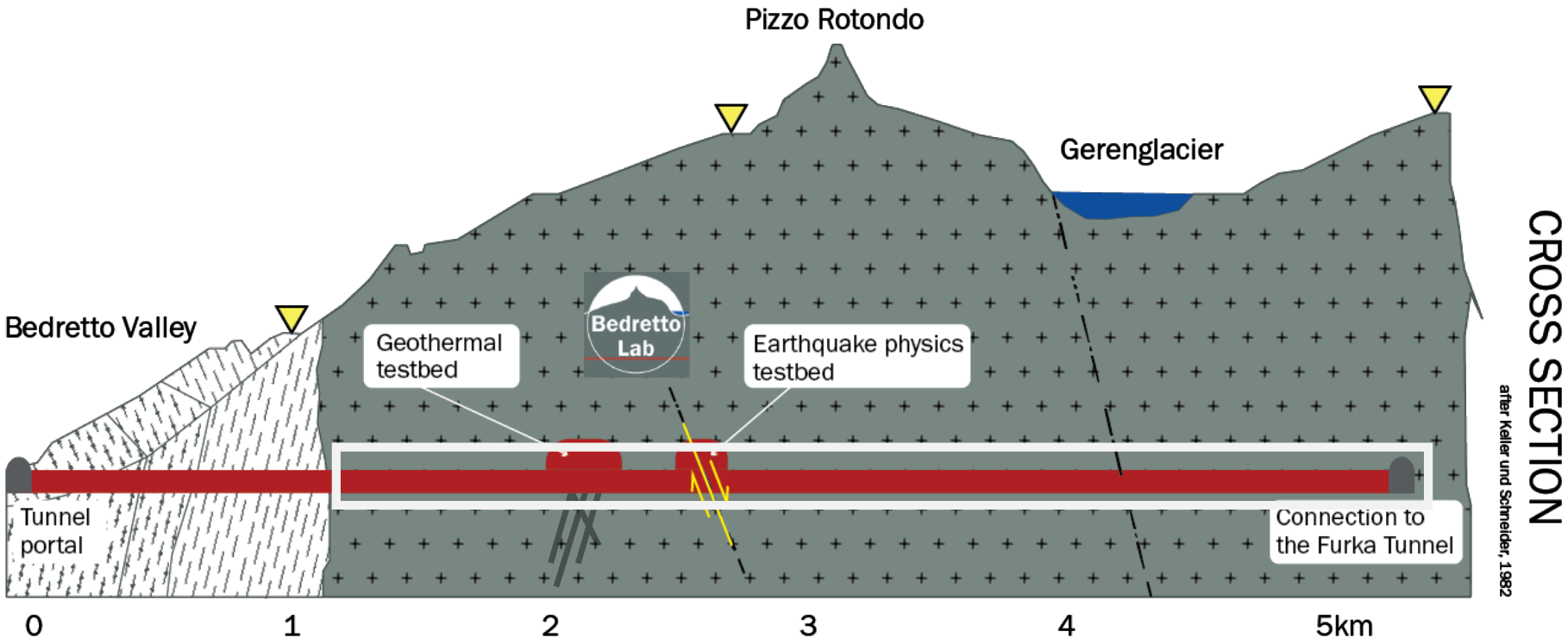

-5.00e-03
5.00e-03
v3 (m/s)
-1.50e+00
1.50e+00
stress change (MPa)
Time: 0.0000 s


Altitude [m]
Northing [m]
Easting [m]
Hours since 23-Apr-2026 08:00:00
Distance wrt Stim1_P2
Altitude [m]
Pressure [MPa]
Stim4_P2
Stim2_P2
Stim1_P2
Stim3_P2
Flow rate [l/min]
Pumps_A
Pumps_B
Apr 23
Apr 24
Apr 25
Apr 26
2026

The Earthquake Physics Testbed



The Deep Life Observatory



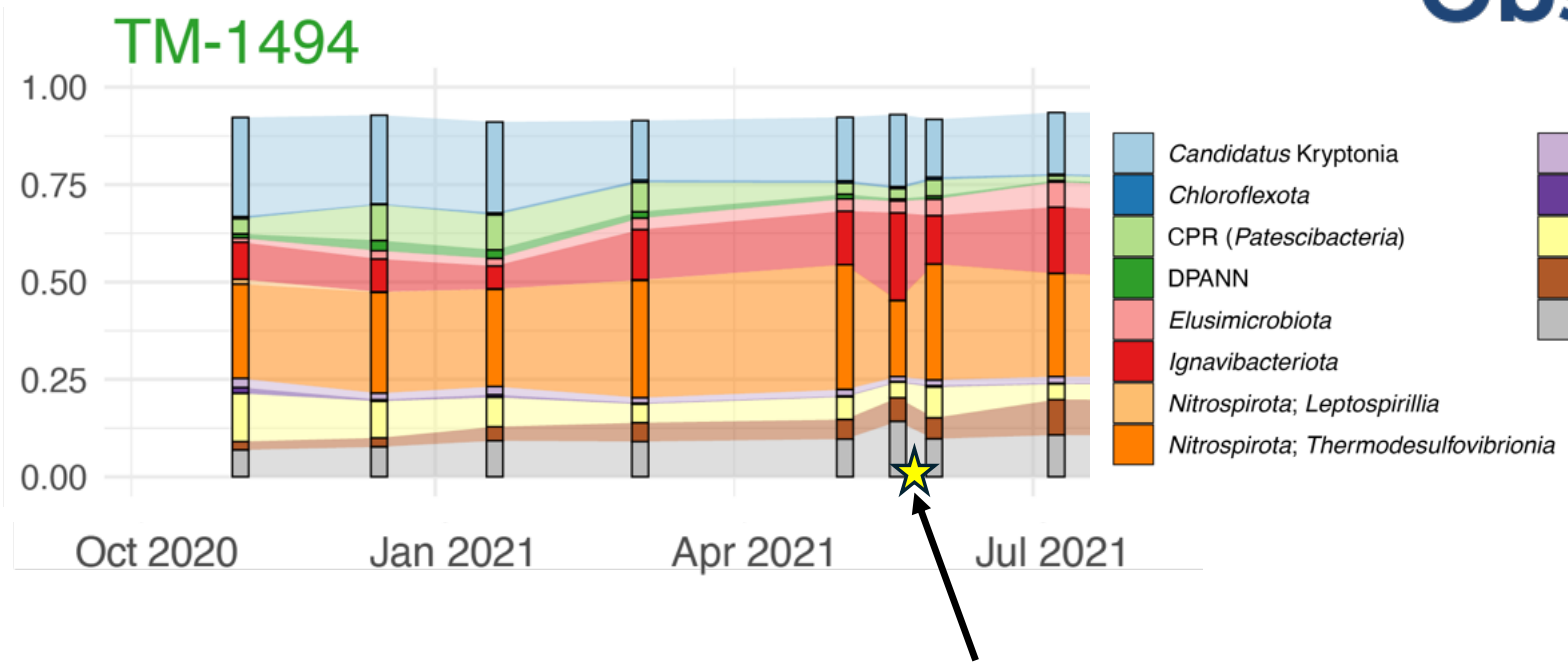
At the BedrettoLab we can study how life develops and evolves in resource-scarce environments

Such environments are relevant e.g. for life on Encelladus, early Mars, or the deep sea.

BedrettoLab

DEEP LIFE

Observatory



Acciardo et al., *Front. Micro.* (2025)

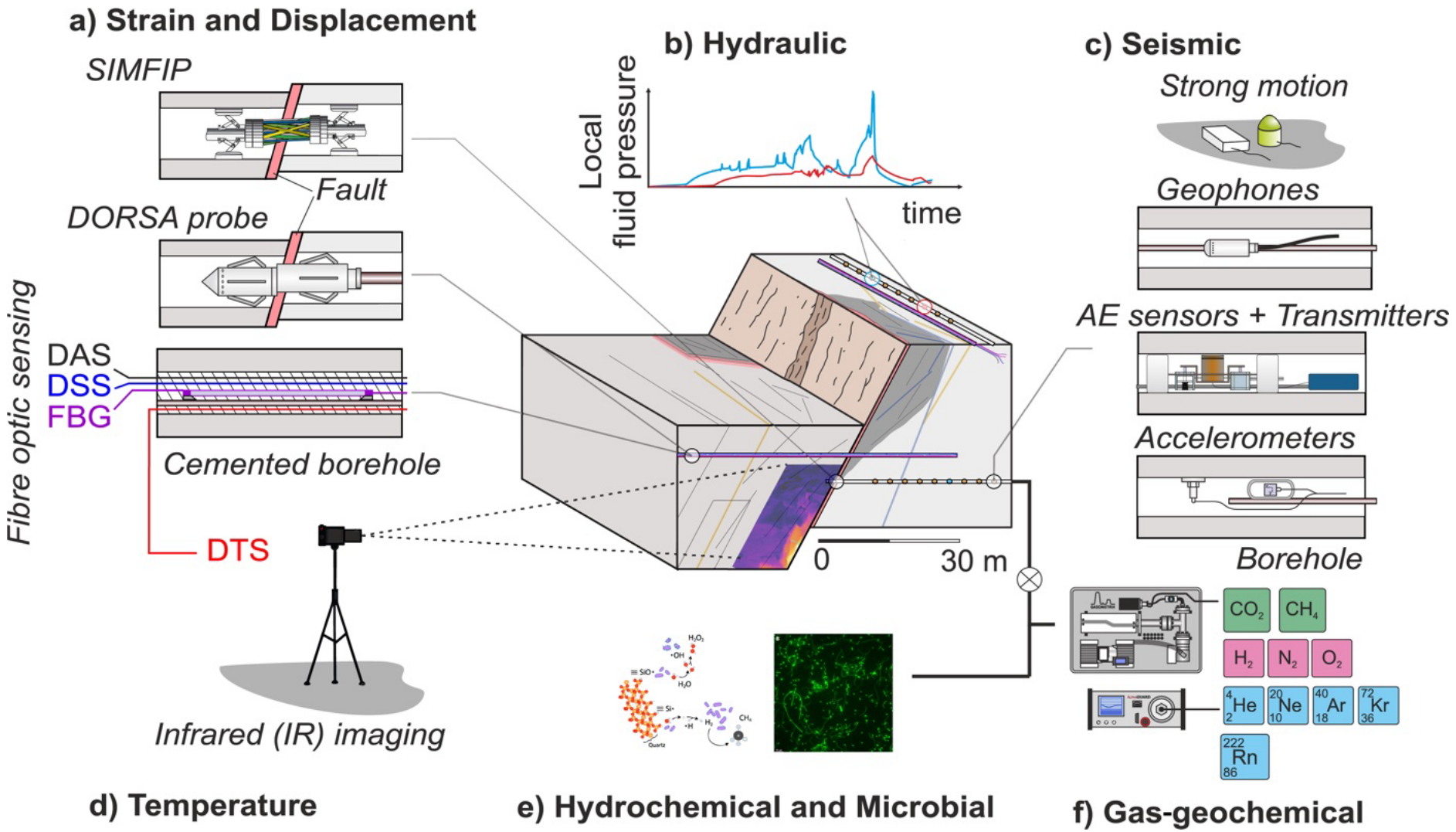
Microseismic events observed along this fault



Andrew Acciardo



Cara Magnabosco



Meier et al., 2026, SEISMICA

The Bedretto approach to Earth science

Tackle first order earth science questions with

- massive on-fault instrumentation
- accompanying numerical models and laboratory experiments

- How do earthquake ruptures nucleate, propagate and stop?
- How do earthquake ruptures interact with fault zone structure & complexity?
- To what extent can we affect the seismic response in fluid injection experiments?
- How far can we improve earthquake predictability?
- …

→ **Controlled earthquake experiments**: intentionally trigger earthquakes where we have the resolution to monitor key processes.